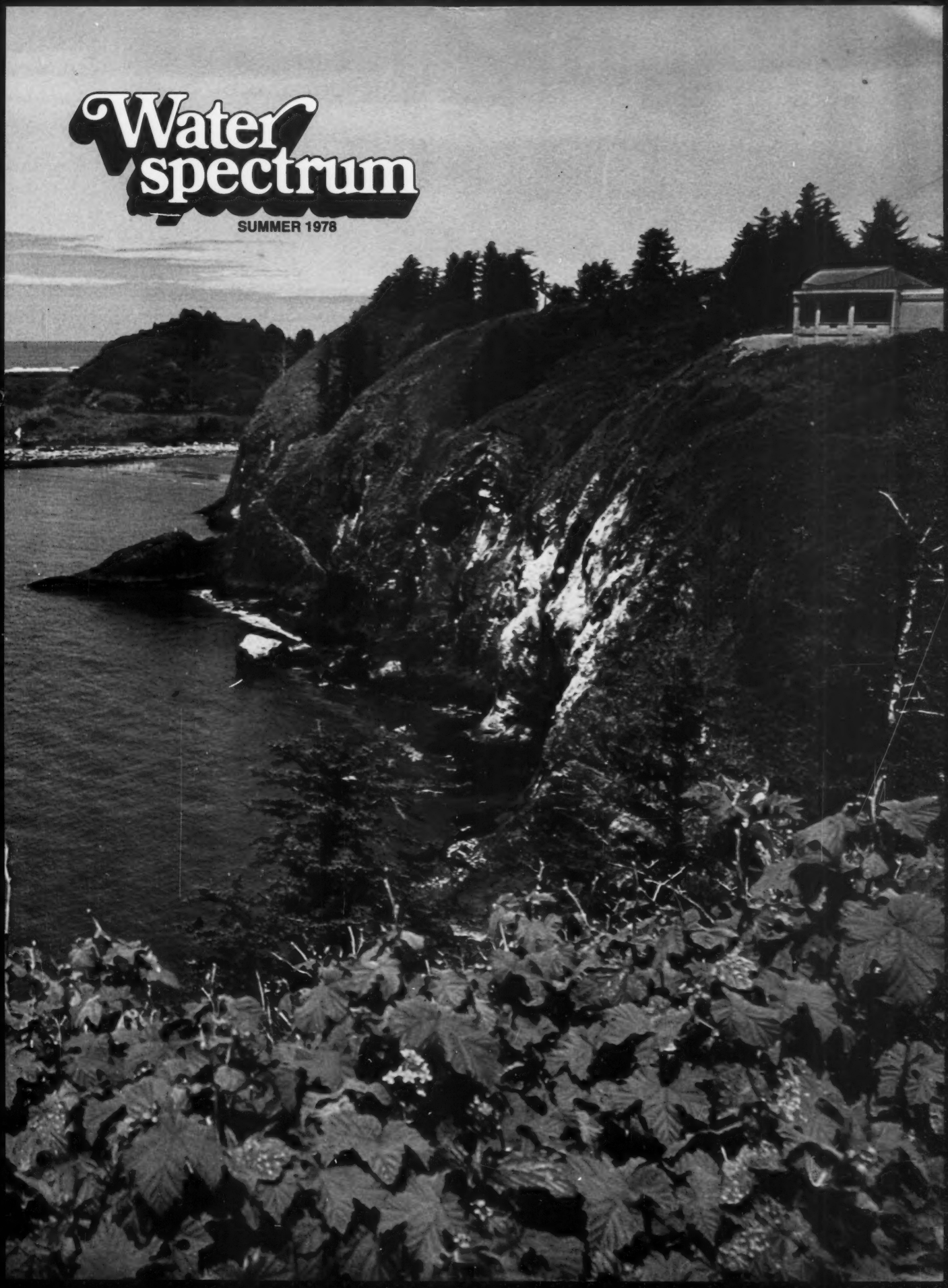
Water spectrum

SUMMER 1978



Water spectrum

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Are our Nation's coastlines endangered to a degree that they should be structurally protected? Differing viewpoints begin on Page 1.

Shore Protection: Yes, at a Price

by **John G. Housley**

Mr. Housley is a coastal engineer with the Planning Division, Directorate of Civil Works, U.S. Army Corps of Engineers in Washington, D.C.

Where the land and sea meet is an arena of constant change. The natural erosive effects of water on rock have now progressed to a stage where much of the interface between the solid and fluid realms has the illusion of permanence, but not permanence itself. It is obvious to almost everyone that a violent storm or a hurricane produces waves that can move and remove large quantities of material. But even on a calm day the sand on the beach is in constant motion under the smallest waves.

Man often selects his frame of reference without consideration of long-term geologic processes. His vision is obscured by either a faulty memory or the assumption that he can do almost anything. These perceptions and attitudes put him in the risky business of fighting the natural processes. Man may win a skirmish, but usually loses the war.

Yet the desire to be at the land-sea interface drives man to build structures, utilities, and appurtenances to make the region more to his liking. Transportation, recreation, industry, fishing, residence, and many other social-cultural activities make it desirable to reshape the environment for man to live, work and play at the shoreline. The pressure for modification of the shorelines is increasing.

Nearly half of this country's population lives in counties which border the oceans, the Gulf of Mexico, or the Great Lakes. As for the cities, 12 of the 13 largest are in the coastal regions. Increased population and industrial pressures mean that the land available for building for the wants of man is decreasing. As relentless progress, agricultural lands are converted to townhouses and shopping centers, dunes are leveled for condominiums and parking

Sand dunes and vegetation help hold in place the dunes and protect the hinterland from storm waves.

The dune's place in the scheme of things is to act as a last natural barrier to flooding of the hinterland during storms. The sand in dunes is too fine for stable beaches, but it does act as an absorber of energy, retreating before the wave onslaught but rebuilding in the later calm. The beach is the primary defense against storm waves: the waves break on the gentle slopes, and energy is consumed in their uprush to the broad, flat berms. Barrier islands are a special case. Beach and dune combinations located offshore, they protect large sounds, lagoons, and embayments. These inland water bodies are connected to the ocean by tidal inlets through the barrier islands, a feature which makes them useful in navigation, but which is harnessed usually at considerable cost.

The geologic processes continue—sometimes faster, sometimes slower, but always relentlessly.

The inherent instability of beaches, dunes, and barrier islands is partially offset by works designed to stabilize, rehabilitate, rebuild, or otherwise provide protection to the institutions man wishes to protect. Not only on the sandy beaches, however, but also on clay bluffs, loamy uplands, sandstone cliffs, and marshy lowlands, the geologic processes continue—sometimes faster, sometimes slower, but always relentlessly.

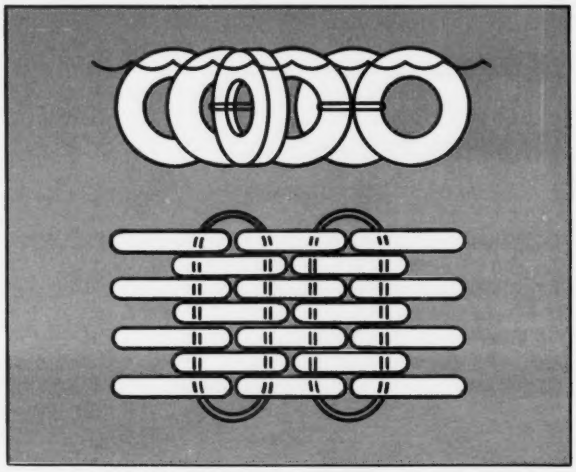
After all the alternatives for handling shore erosion are analyzed, then man makes his choice. It may be governed by economic, environmental, social, aesthetic, or political criteria, or, more usually, a combination of all of them. For whatever reasons, the choices are made and the price paid. Usually not every segment of society is happy with the choice. The conflicts of values and priorities of uses for that small strip known as the coastal zone guarantee that some segment will not be satisfied. However, the political process attempts to accomodate a majority of interests.

A breakwater protects the inlet to Channel Islands Harbor, California. Sand accreting on the updrift side of the inlet (left) has been pumped to a beach past the point in the background, leaving a small pocket in the shoreline.

The U.S. Army Corps of Engineers has been involved with coastal engineering since Congress in 1930 authorized it, in cooperation with state agencies, to investigate shore protection problems with a view to devising effective means to prevent erosion. In 1946, Congress first authorized the expenditure of Federal funds to assist in the construction of projects to protect publicly-owned shores. This authority was amended in 1956 and 1962 to increase the proportion of costs borne by the Federal government, and to provide that the cost of studies be completely a Federal responsibility. Under these authorities, and under a 1968 law which authorized investigation and construction of projects to mitigate shore damages caused by navigation works, the Corps has constructed nearly 100 projects for beach erosion control or for multiple purposes that include beach erosion control.

Corps erosion control projects range from offshore breakwaters to seawalls to revetments to beach fill. A **breakwater** intercepts waves that would impinge on a beach and move material. It also performs two other important tasks: it creates

Figure 1. At Pickering Beach, Delaware, on the Delaware Bay, two types of scrap-tire floating breakwaters will be studied as part of the Shoreline Erosion Control Demonstration Project. They will be each 400-feet long, but of differing designs. Anchored some 800 feet from shore, they will float in about four feet of water at low tide. Plantings of several species of grasses along the mean high water line will be partly shielded by the breakwaters, partly exposed, so that researchers can assess the degree of protection required to allow the vegetation to develop.

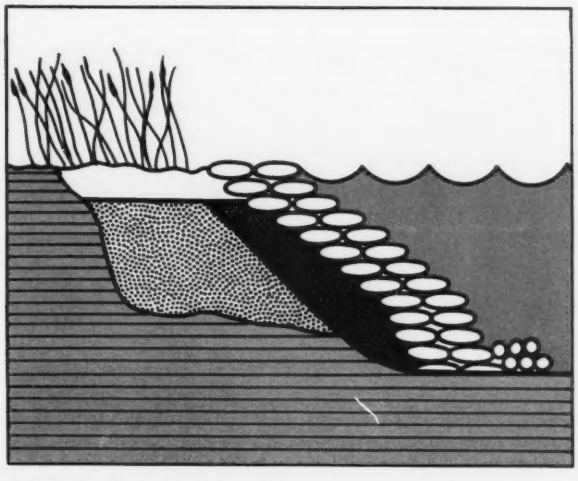


a quiet area in the lee of the structure, where boats can find refuge in times of storms and where dredges can operate without heavy waves, and it acts as a sand trap by reducing the wave turbulence and causing whatever sand load is being carried by the currents to be deposited in the breakwater's lee.

A few years ago the Corps built an offshore breakwater at Channel Islands Harbor, California. The breakwater traps nearly all of the southward-moving littoral drift. In doing so, it prevents the loss of sands to the submarine Hueneme Canyon, stops shoaling of the Channel Islands Harbor entrance, and protects a floating dredge used to bypass the trapped sand across the harbor entrance to the downdrift shore.

Groins are built singly or in sets known as groin fields. The purpose of a groin is to provide an obstruction that retains a beach, or at least retards its erosion, by jutting from the beach seaward and intercepting the littoral drift. Sand accretes on the updrift side and is eroded on the downdrift side. In a groin field, short pocket beaches are formed and are aligned perpendicular to the wave direction, so that each one is relatively stable. Stone, timber, steel, and concrete are common materials for groin construction. The groin field at Westhampton Beach, New York, for example, has nine groins of stone construction and has created a relatively stable framework for a beach constructed of sand pumped into the field. Erosion of the beach downdrift is a significant side effect.

Figure 2. The Shoreline Erosion Control Demonstration Project at Oak Harbor, Washington, will test four types of revetments intended to prevent waves from attacking the 35-foot high bluff during storms and abnormally high tides. Sand-cement filled bags laid on the slope, gabion mats, timber bulkheads, and scrap tires strung on railroad tie pilings, all placed at the toe of the bluff, will be studied. Filters and toe protection will be investigated. Vegetation will be used to control surface runoff.



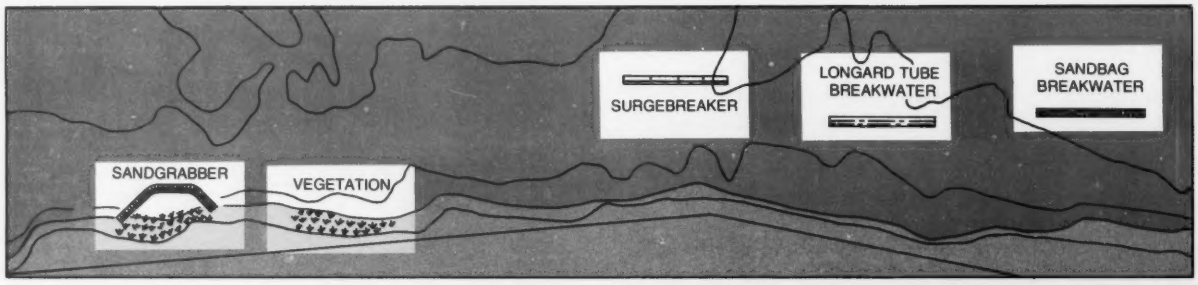
Waves top the Channel Islands Harbor breakwater, but most of their force is dissipated.

Bulkheads and **seawalls** are solid structures of any material that will be wear-resistant. They keep the sea from directly eroding the beach by separating the two. The bulkhead is usually designed to keep the land in place, while the seawall is designed to keep the sea out. Some structures are massive, like the famous San Francisco seawall, built shortly after the turn of the century, while others are relatively fragile and thus susceptible to damage and high maintenance costs.

A **revetment** can be considered a type of seawall or bulkhead, and indeed the three names are sometimes used interchangeably. Typically a revetment is of some material, like stone or concrete blocks, that is laid directly on the dune or bluff to prevent wave attack from removing sand or soil.

The last major type of shore protection structure is the **protective beach,** built by placing sand of suitable grain size in a particular shape on a beach to increase its dimensions and thus its wave force absorbing potential. The sand is brought in by dredge, truck, or other means. The sand will be worked on by the natural processes and will need to be replenished at some future date. Periodic replenishment, called artificial beach nourishment, is often less costly than building massive

Figure 3. At Basin Bayou State Recreation Area, on the Choctawhatchee Bay near Valparaiso, Florida, the Shoreline Erosion Control Demonstration Project will examine the effects of a variety of breakwaters, bulkheads, and vegetation. The fine sand beach at Basin Bayou is 2,500 feet long and backed by bluffs up to 10 feet high. The breakwaters, one a concrete structure, another a sand-filled plastic tube, and a third constructed of several types of sandbags, will be 200 feet from shore. Behind one of the breakwaters, a fence-and-sandbag bulkhead will help protect the higher bluffs. Not far away will be a patented device made of cinderblocks. Several types of grasses will be planted both behind the structures and at exposed sites.



shore protection structures like breakwaters and seawalls. It also has the advantage of providing a beach for recreation at the same time that it protects the backshore from storm damage.

In addition to structural techniques, vegetation and institutional measures can help deal with shore erosion problems. Grasses like panic grass, American and European breachgrasses, and sea oats are often used in dune building and stabilization. They are considered generally successful, although few quantitative data are available. In the intertidal zone, encouraging the natural spread of marshgrasses is now being studied extensively. Intertidal zone vegetation is likely to be especially useful in sheltered areas where wave action is slight and when employed in conjunction with other protection, such as a floating breakwater, that aids the establishment of the plants.

Most problem areas are not eligible for Federal assistance.

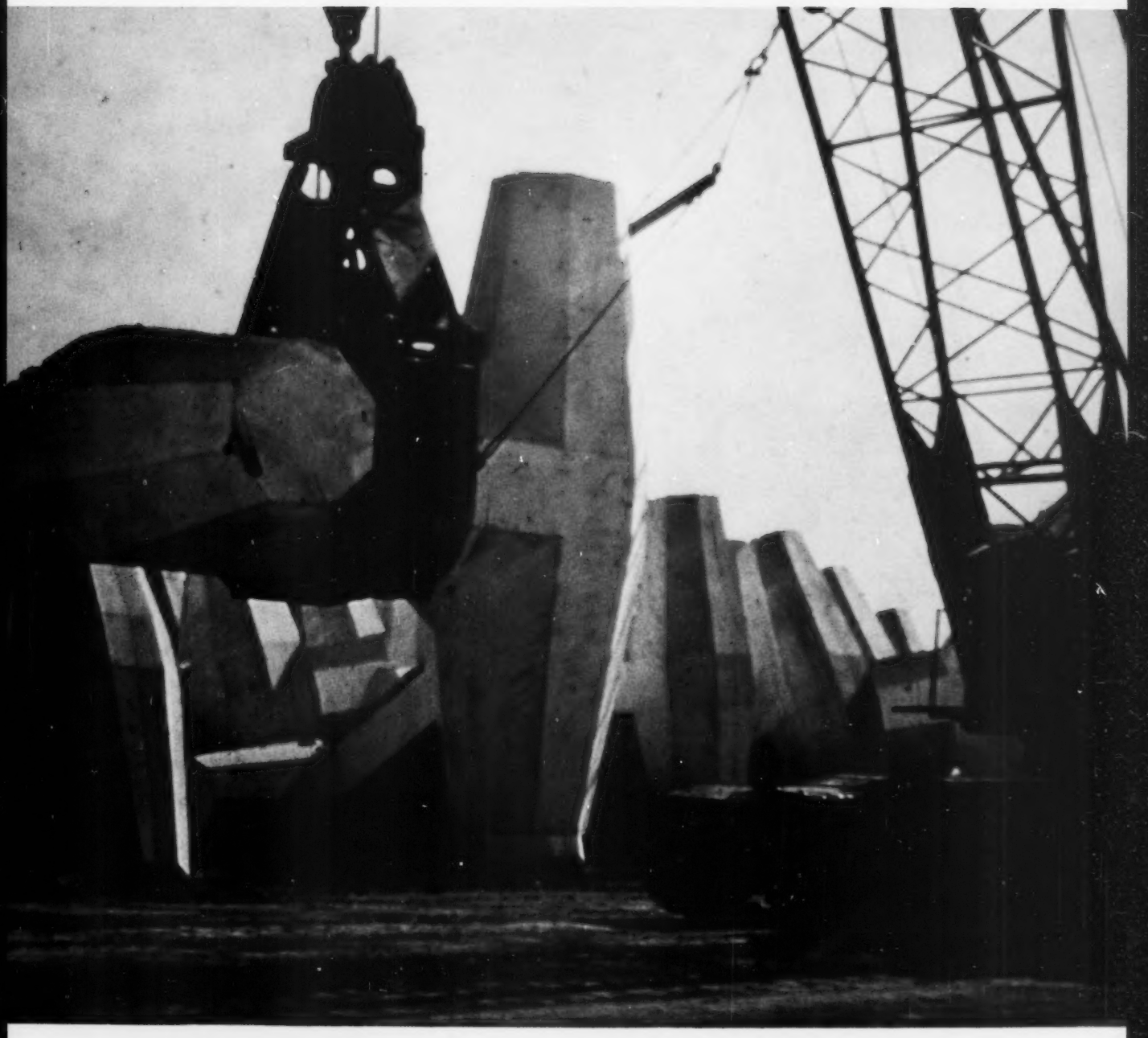
Institutional techniques for dealing with erosion prohibit, restrict, prevent, or remove development along the shoreline. They are of little help to the property owner whose front yard is disappearing, but they can reduce the presence of development that, given the march of natural processes, will at some later date require protection or rescue, often at public expense.

The success of any of the structural techniques for controlling shore erosion depends upon, first, a knowledge and appreciation of the natural forces at work and, second, a project design that accounts for those forces and reaches an accommodation with them. It must be kept in mind that sooner or later the natural forces will have their way. No structure is permanent. Effective and long-lasting structures can be built, but the more effective and durable they are, the more they cost. The questions that must be answered before a project can be designed are: what kind of protection do you want? how much of it? how much are you willing to spend?

The degree and cost of protection selected depend on who is doing the selecting, that is, on who is the landowner. Since the sine qua non of the Federal government's involvement in shore protection projects is the public ownership or public use of those shore lands, it is well to remember that 75 percent of the shoreline of the country, excluding Alaska, is privately owned. Thus, most problem areas are not eligible for Federal assistance in the usual sense. In 1974, however, Congress authorized the Shoreline Erosion Control Demonstration Program. The legislation directs the Corps to conduct a 5-year, $8 million program of developing and demonstrating low-cost erosion control methods, both structural and vegetative, on sheltered or inland waters around the shorelines of the United States.

The dredge at work at Channel Islands Harbor, pumping sand around the inlet.

The precast concrete armor units that protect the toe of the Humboldt Jetty weigh 42 tons each. (Photo at right)



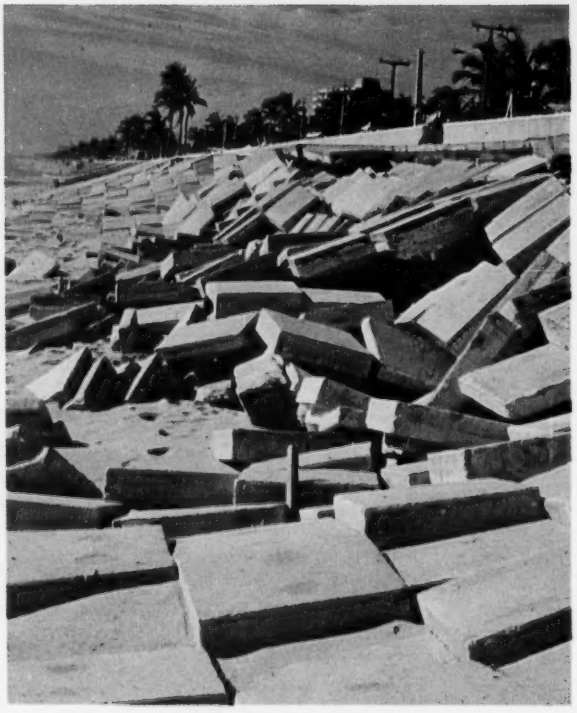
The aim of the program is not the solution of the shoreline erosion problems of a particular site, but the acquisition of knowledge about devices, techniques, and schemes for controlling shoreline erosion, and the dissemination of this knowledge to the people faced with the problems. This process of technical assistance, in the form of the evaluation of structural and functional suitability, cost, and life expectancy, will enable the owners of eroding land to choose a solution to fit their particular situations.

The goal of finding erosion control techniques that an owner of private property can install himself or contract to have installed mandates that the techniques be both low-cost

Intertidal plantings protect the toe of a bulkhead at Pine Knoll Shores, North Carolina.

and of simple design. "Low-cost" was not defined in the authorizing legislation, and so a working definition has been adopted for the demonstration program. But it seems clear that a real definition is highly subjective and dependent on the value of the land to be protected. A farmer losing some pasture acreage has a notion of low cost different from that of a beach cottage owner witnessing a continually narrowing front yard, and again different from that of an industrialist whose plant is damaged by waterfront erosion. In order to address the problems of a large number of homeowners, the Corps has adopted maximum cost figures of $50 and $125 per front foot of device for the demonstration projects. The first figure is for materials only, assuming the property owners install the devices themselves, and the second is for materials and labor, assuming a contractor would be hired to do the work, possibly using heavy equipment.

With the help of a 15-member panel of advisors, the Corps has selected 16 sites for demonstration projects, within the statutory requirement that at least two sites be on each of the coastal zones—Atlantic, Gulf, Pacific, Alaska, and the Great Lakes. Sites were selected where the wave erosion problem is clear, other erosion control devices—which would conceal the effects of the techniques under study—are absent, and the public can visit the projects. Because the designs to be studied are intended to exist in low-energy wave action situations only, sites were chosen where waves would not exceed six feet in height. Inland tidal waters and the Great Lakes shores of course meet this requirement, but so do some coastal shores, where natural features reduce the height of waves before they break upon the shore.



Not all shore protection works withstand the forces of the sea for long, as evidenced by this concrete block revetment on the east coast of Florida.

Shoreline erosion is a problem on banks as well as beaches, as the situation at Geneva State Park, Ohio, illustrates.

After the sites were chosen, the Corps District offices selected the low-cost erosion control methods that looked most promising for each site. Materials and techniques were selected to be compatible with the region where the projects would be built. For example, in Alaska discarded oil drums are plentiful and may prove useful as groins and bulkheads; in Florida mangrove trees, a common form of vegetation there, will be studied for their erosion control effects in the intertidal zone. Among the techniques to be studied are:

- aluminum bulkheads
- bins or cribs, made of concrete, steel, aluminum, or wood, used as bulkheads or revetments
- gabions used as revetments or to build groins
- large, coated fabric tubes, filled in place with sand, used as breakwaters, bulkheads, and groins
- stone or concrete rip-rap revetments
- sand- or concrete-filled fabric bags used as groins, breakwaters, and bulkheads
- precast concrete sheet piling, possibly pre-stressed, used as bulkheads
- rubble mound groins and breakwaters
- Z-wall offshore breakwaters of steel or concrete
- scrap-tire bulkheads, revetments, and floating breakwaters
- vegetation to stabilize dunes and the intertidal zone

A number of patented devices are being installed at demonstration sites around the country. While the Corps does not endorse the products, since they are being sold to many people, the program will evaluate them and make the data available to potential users.

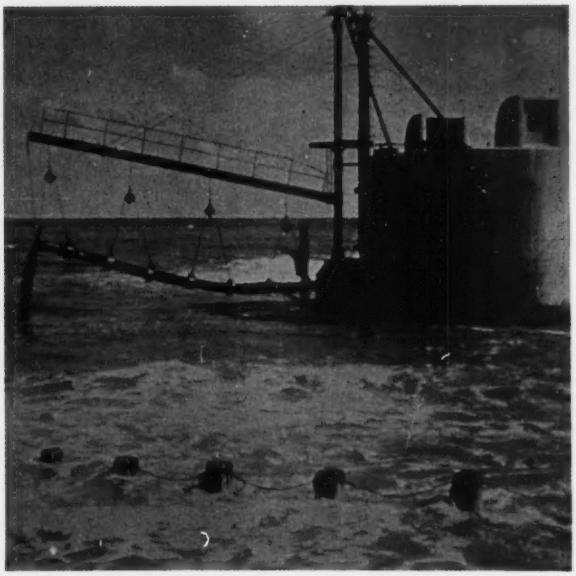
Following construction, the projects will be monitored intensively.

Some of these methods are oft-tried techniques on which better performance and cost data are needed; others are innovations getting off the drawing boards for the first time. Many are adaptations of large-scale technology; a few appear to be suited specifically to low energy, low cost, small scale applications.

Intertidal plantings slow erosion of a North Carolina golf course.

We can find a reasonable accommodation between man's desires and the forces of nature.

The projects are now in the later stages of design or are under construction. Each will combine several techniques so that as many as possible can be studied. The variety of shoreforms, wave climates, and devices should provide information useful to a broad range of shoreline conditions, erosion control goals, and landowners' pocketbooks. Following construction, the projects will be monitored intensively for several years, and the data analyzed. Figs. 1 and 2 illustrate how a variety of techniques will be applied at two project sites.



A sand pumping plant in Florida moves sand around an inlet to compensate for erosion on the downdrift side.

Natural vegetation helps hold this Cape Hatteras dune in place, while a fence traps sand and assists nature in building a dune.

Storms move dunes, and those who build on them will pay the price, as did the owners of these New Jersey homes.

There has been much discussion in recent years of allowing natural processes to continue to act on the shore. And these are precisely the processes that man tries to stop with most shore protection programs. To reach a rational accomodation with nature, some guiding principles need to be understood. First: don't build in the "floodplains." This is so intuitively obvious that one wonders why we have not yet learned that there is a tremendous price to pay for the privilege of doing so. Granted, however, that there are short-term gains from development of the "floodplains," hard decisions must then be made about how to amortize the risks. And second: don't fight nature, but use the resources in a way which allows for natural variability. A beach and dune system is the best natural defense against encroachment by the sea. The sands that form the beaches and dunes must be replenished and protected—not just at a particular trouble spot, but taking into account an entire physiographic region. It does little good to build a fine storm-resistant beach at the expense of a beach to the downdrift side of the problem area. And to build dunes by vegetation or sand fences is useless if adjacent dunes are bulldozed down to make building sites or if beach buggys are allowed to roam the dunes, destroying the vegetation that maintains them.

A combination of land use management and structural techniques can form the basis of shore protection measures that are flexible enough to satisfy most of man's needs and that provide an affordable buffer against damage by storm waves. If man's activities in shoreline regions are limited to those truly dependent on proximity to water or shoreline and if the protection schemes used allow for the movement of sand as a natural part of the scheme rather than try to halt all motion, we can find a reasonable accommodation between man's desires and the forces of nature. If, on the other hand, we want to stop the motion of sand entirely, we have the technology, but not the purse. ■

Magic Beaches: No

by **D. W. Bennett**
Mr. Bennett is Executive Director, American Littoral Society, Sandy Hook, New Jersey.

Consider the way the system works now. Say you want to build a house on the beach. The official response is, in effect: go ahead and build it; the Federal government will encourage and protect you. It will encourage you by funding highways to your beach town; it will help build bridges over to it. It will help provide sewerage and fresh water supply. It will insure you against flood damage. And if the ocean gets rambunctious (and it will), the Federal government will pile rocks in the water to make magic beaches.

The trouble is that this system that benefits the beachfront is unnatural. Let us look at how nature treats beaches first and then at some of the ways engineers have tried to stem the tide. Then let us propose a solution to the problem, a natural solution.

Barrier beaches move shoreward and their inlets migrate.

To set the geological/biological scene first: the term "barrier beach" covers a number of similar and related nearshore geological formations. These include barrier islands—true sand islands separated from land by water; barrier spits or sandy peninsulas jutting into the water parallel to the coastline and similar to islands—except they are connected to the mainland so water circulation patterns are different from true islands; and sandy foreshores without bays behind them even though they may be near islands and spits. Examples of these latter would be the Hamptons on Long Island, the beaches from Monmouth Beach to Manasquan Inlet in New Jersey, and the Myrtle Beach area of South Carolina.

Barrier beaches have certain features in common: sandy, struck by ocean waves, often long (Padre Island off Texas extends 109 miles) and narrow, a quarter to a half a mile wide; low elevation (20 feet or less, though sand hills can reach 100 feet); dunes behind the foreshore, flat behind the dune lines; and fringed on the backside with salt marshes, sometimes a mile wide. Behind the marshes and honeycombing them are passes or thorofares, wide or narrow, shallow or deep, muddy or sandy. Also, barrier beaches move shoreward and their inlets migrate. There are about 280 barrier islands and spits between New Hampshire and Texas; 70 are in some form of permanent protection status; 80 are already heavily developed; and the rest are privately owned and undeveloped.

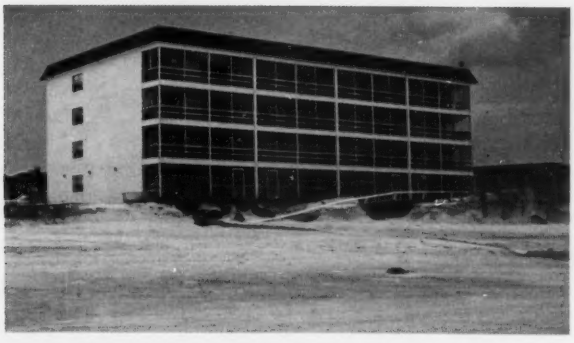


Photo at left shows a motel at Panama City, Florida, behind first low dune line, in August 1975. During Hurricane Louise in October 1975, the structure was damaged by hurricane tides and waves cutting through the dune line.

Photos by the author.

Even this frugal description—narrow, flat, exposed to ocean waters, and made of sand—should have dictated long ago how barrier beaches should be used. In a word—carefully. But care has not been exercised. Barrier beaches have been misused and over-developed, and their future is in peril. This peril is the result of neglecting the most important aspect of beaches—that they must move to survive. They have evolved—to survive—by giving in to the severest of ocean storms, permitting wave waters to tear up and over them. Then when the storm subsides, the beach restores itself and awaits the next onslaught. This is a fine natural system, and it works as long as no one tries to establish a permanent foothold on the barrier beach. Native Americans were smart enough to visit the beaches for hunting or fishing and to withdraw when the ocean got rough. Latter-day Americans misunderstood the nature of beaches and came onto them and built things there. Now, when storms hit, the inhabitants have structures against which to measure the reach of the sea. When it reaches too close (when the beach goes away), the cry is not: "Let us take ourselves and our houses away till the storm abates," but instead, "Let us stop the sea, so we can stay here forever."

It won't work, but the standard approach (let's do something) usually wins out over the more sensible approach, which is to ask first what is really happening before we "do something." The somethings include jetties or groins, which propose to stop beach change by slowing littoral drift so that sand is deposited on the beach, and sea walls, which simply keep the ocean from pouring onto the land. Neither works, but both give the appearance of thought and action.

One very good example of doing something without thinking took place in northern New Jersey two winters ago. A stretch of beach along Long Branch was slowly washing away, as it had been for years. In an effort, any effort, to hold the beach, the City (with some funds from the State) contracted with a firm to stack oversized cinder blocks parallel to the waterline about half way between high and low tides, the theory being that this breaker pile would somehow slow down the wave's power and deposit sand on the beach. The device was called "Sandgrabber." What really happened, at least for a day or so, was that the beach sand was simply

transferred from the berm to the waterline. After two days, a northeaster came along and washed the Sandgrabber away, except for a few pieces of block and some long sections of reinforcing rod which remain, jutting out of the sand, rusting quietly with the seasons.

The temptation to "do something" is often too strong to resist.

The temptation to "do something" is often too strong to resist. Thus, tires, piles of concrete, sewer pipes, logs, branches, almost any material is dumped into the sea to build beaches. Once, during the construction of an offshore outfall, a little bit of beach built up around the cofferdam that jutted out into the surf. The upland owner was full of joy—he had a magic beach. He pleaded with the sewer authorities to leave the cofferdam in after construction. They didn't, and when it was pulled the beach went away.

That's what beaches on the Atlantic Coast are doing—going away. There are several reasons:

- Sea level is rising at a rate of about an inch every 10 years. It's gone up a foot in the last century.
- No new beach material is being added to the system. The rivers have either stopped eroding the uplands from a past geological epoch, or the rivers have been dammed so that their cargo of sand and silt no longer reaches the sea.
- Much beach material is lost to the system. It washes offshore during storms, it is blown back across the barrier beaches during severe onshore storms, or it moves downstream into inlets, where it then goes either into the inlet or offshore.

The beach is losing its major armament—sand. Man has not helped. For it is a fact that every man-made device put into the sea to protect barrier beach islands has done just the opposite. This is because a choice has been made, a subjective choice, that beaches should have certain heights and widths and that their major function is to serve as developable real estate. It is a mistake to ignore the beach's primary function as an energy absorber, with other uses to be considered second. Once human decisions are made that (1) people shall live on barrier beaches, (2) inlets shall be stabilized for navigation, and (3) beaches should maintain certain profiles,

A private home on the western ocean edge of Panama City immediately after Hurricane Louise. No front yard, no back yard—just a house on stilts.

we put ourselves in a position where whatever we do structurally to defend these three decisions will, ultimately, be bad for beaches.

There is still time to save the barrier beach islands that have not been developed—by purchasing them or gaining conservation easements so that construction on them is prevented. While it will not be easy to raise the kind of money needed for such an approach, it is, essentially, a direct and rather simple problem to define and solve. But the problem of what to do on developed barrier beaches almost defies solution. It pits natural systems, which will win eventually, against human systems, which now have equipment and money to make drastic changes to the natural system over the shorter term.

It is tempting to turn the problem over completely to nature, which will send along its unpopular guests, the hurricane or the northeaster, to eventually wipe away efforts to colonize and stabilize beaches. We would be treated to dramatic scenes of houses toppling into the sea, giant condominiums easing their way into inlets, and great sheets of blacktop awash. It would make a fine disaster movie: "Barrier Beach Blast" or "Going, Going, Groin!"

It is probably sociologically and politically impossible for a decision to be made to walk away from the problem and let nature have its way. Few would argue that destruction of property is a humane or even necessary step. It would be like plowing suburban houses under to restore farm land—tempting, but unrealistic. If that alternative is discarded, what steps are left?

In places where building has not taken place too close to the ocean, it needs to be kept that way. One would think that this lesson of beach setback would have been learned at least within the last few decades. But the following illustrates that it has not:

The sea . . . penalizes silly land users everywhere equally.

At a meeting on barrier islands held in Savannah last December, the group present was shown a slide of the seawall and groin fields along a strip of the New Jersey shore. There were giggles of geological knowingness. "Ridiculous," they seemed to be saying, "those northerners have built themselves a sour pickle."

Then I recalled that just the day before the meeting I had wandered up the coast to Hilton Head to see what man had wrought since my last visit in the mid-60s. Same news. Hilton Head was beginning to slide into the surf (or, rather, the surf was beginning to slide up on Hilton Head). Several oceanfront owners had stacked rocks and logs where their front lawns were being etched by the tides. It occurred to me that what New Jersey had failed to learn in the 1900s, South Carolina was failing to learn in the 1970s. The sea plays no regional favorites and penalizes silly land users everywhere equally.

Examples follow our coastlines: beach homes have tumbled into the sea this winter in Charlestown, Rhode Island, and on Long Island, New York. Cape Hatteras Lighthouse is getting wet feet. Miami Beach is pumping millions of yards of sand onto its starved beaches; New Jersey just opened a new $2 million bathing pavilion at Island Beach State Park less than 300 feet from the water; Panama City, Florida, answered its multi-million dollar damage from Hurricane Louise in 1975 with bulldozed sand. The West Coast is no less foolhardy.

Those who ignore history's geology lessons are doomed repeatedly to have sand in their living rooms. We need a system that anticipates and welcomes further encroachment by the sea—both gradual (sea level rise) and sudden (hurricanes). The system should include the following steps:

The beach at Gateway National Recreation Area, Sandy Hook, New Jersey, after the winter storms of 1978. Left photo depicts wave erosion of the beach; the damaged bath house in the background has since been torn down. This beach has lost about 100 yards of width in the last 10 years. The view at right, taken in the same direction, shows efforts to keep the road open by bulldozing sand back onto the beach. This operation cost $8,000 and is doomed to be repeated.

- Continued purchase of beachfront land, including whole barrier islands, by public and private agencies, to prevent their being developed. This is by far the cheapest approach to beach protection.
- A phasing out of any public subsidies to protect beachfront investments where they should not be. This means less Federal aid for bridges over to barrier islands, less Federal aid for water and sewer projects on beaches, and, most importantly, a restructuring of the Federal flood insurance program to discourage rather than encourage beachfront construction. I am reminded of a plan to build a beach

Beach berm cut by winter storms of 1978 in Lavalette, New Jersey. The first row of homes is about 50 yards west of this cut.

Construction underway at Lavalette during winter storms. Footings are about 75 yards back of high water mark.

condominium. The designer explained that the ground floor would consist of parking spaces, all sheathed in such a way that when a storm tide came, only the sheathing and the cars would be lost. Surely we can come up with a system that does better than answer a tidal storm with drowned cars and exploding curtain walls. (Flood insurance should be further modified to provide for insurance only if a damaged house is not replaced or rebuilt on the beach. And States and the Federal government should earmark funds to buy up flooded land after storms, before rebuilding begins.)

■ A conscious decision that funds for remedial beach action will not be automatically forthcoming. As long as people know that agencies will bail them out of difficulty they will continue to build where they shouldn't and cry for help to prolong their folly. Maintaining what's already on the ocean's floodplain is tough enough; permitting new investment is insane.

The major cause of concern about beach erosion or movement is the price of beachfront land. It is so easy to make money buying and selling the stuff that it is no wonder real estate interests and the towns that tax them resist any efforts to bar beach development. Ample evidence exists to show that building too close to the ocean is dumb. But it's not illegal. It is possible to make it illegal by zoning beachfront land in such a way that it cannot be built upon. Other sensitive or critical areas—floodplains, wetlands, steep slopes—have been handled this way, but in most states, zoning is a municipal matter and municipalities are not likely to zone away high tax ratables, especially in beachfront situations when they can have the ratables and still not be responsible for the damage repairs.

Herein lies the germ of an idea that will need Federal/State cooperation: should we not turn over 100 percent of beachfront stabilization costs to the municipalities that have the zoning power? After all, what is more fair than to leave this responsibility in the hands of those with the power to do something about the problem?

But all this is in the future and every indication is that the system is not about to be changed quickly. There still remains the question of what to do about existing beachfront development threatened by the sea.

I suggest that, in the words of Paul Godfrey,* "man should interfere only to correct past errors and to protect the barriers from future actions which will jeopardize their natural recovery capabilities." Until now, beach protection has been like a person trying to even the four legs of a chair by randomly cutting a section off each leg and then trying it for size. It has been patchwork here, panic there—a dash of rock and wood in one place, a few million cubic yards of sand in another. It has been one beach town pitted against the one downstream as each tries to catch as much of the littoral drift sand as it can. It has been a pastiche of pseudosolutions, getting more costly each year, all the while perpetuating a belief that somehow, somewhere, someone will come up with a magic solution and the ocean will go away.

As a starter, the geology of beaches needs to be understood by both users and protectors. One basic principle is that the beach system, from inlet to inlet, must be considered as a

*"Comparative Ecology of East Coast Barrier Islands: Hydrology, Soil Vegetation," contained in the proceedings of the Barrier Islands Workshop in Annapolis, Maryland, May 17-18, 1976.

North Miami, shown in 1973 in its beachless state. Sand can be brought in to restore beaches like this, but the cost is high and the solution temporary.

Building too close to the ocean is dumb. But it's not illegal.

whole, because the sand starts at the updrift end of the beach system and goes to the other end. Left to its devices, a barrier beach will move, and inlets will migrate in the same direction. Once we have made the decision to stabilize inlets, we must treat the beach between two inlets as a system. Then, it must be decided what sort of beach is needed and wanted, keeping in mind that we want a beach with "natural recovery capabilities."

The beach that is needed is one that responds naturally to the sea. It must be able to move in normal winter and summer configurations, and it must be able to withstand storms by giving ground. The beach needs to be wide, it needs to slope naturally, it needs dunes for sand storage, and it needs places to move landward during storms. Also, it needs just the right sized sand grains, so it doesn't move on too quickly (sand grains too small) or try to stand up to storms when it should move (sand grain sizes too big).

If a decision to treat a beach this way is made, zoning regulations must prevent development from encroaching seaward as the beach is built. Also, the public must be assured of access to these new beaches. By access, I mean plenty of pathways over to the beach, clearly marked and freely accessible, so that the inland resident feels welcome on the beach.

The construction of such a beach can probably be left to engineers. Its design—its concept—however, must first be decided upon by geologists and biologists, by scientists whose expertise is in natural beach functions, not in how to perpetuate their artificiality. Only when the sciences and the technologies work together will a reasonable solution be found.

Non-structural techniques are the key. Once the decision to "remake" a beach is made (and we are assuming here that it is agreed it will work and should be done), then one barrier beach, from inlet to inlet, is completely designed and built, by adding sand, most of it at the updrift end, and then planning to catch that sand at the downdrift end, taking it back and adding it to the system again, closing the loop. The cost of such a plan is enormous, but if it can be shown that it will work and that the beach will be useful, it is just a matter of figuring costs and benefits and seeing how they match up. However, the increased value of private property should not be a part of the cost/benefit measurement.

I suspect that such a beach will cost millions of dollars per mile to construct and additional millions a year to sustain. And even this drastic approach will not work forever. Sea level will continue to rise, some beach sand will still be lost offshore and into inlets, and sand grain sizes will grow smaller as sand is passed again and again through the system. But, there is a great advantage here, for it will mean that once and for all, everyone will have faced up to the problem in practical terms, so practical that they might be applicable only on selected beaches, and the others, rather than being hammered to death piecemeal by a jetty here and some stones there, will be left to go their merry way.

A final note: this article was written just after a violent storm in New Jersey. Three-year old apartments in Sea Bright, built right behind the seawall, had to be evacuated as a "mass of brown water, 5-feet deep, moved down Ocean Avenue." What's so sad is that the evacuees were surprised.■

A barrier island groin field, showing buildup of sand on the downstream side of each groin and erosion on the upstream side. The beach here makes up about half the width of the island.

"HARNESSING THE HABITAT"

A PROPOSAL

by **Edward H. Hanses**

The phrase "Harnessing the Habitat" is one which the author has coined to serve as a descriptor for his system of multipurpose forest management and as the title of his forthcoming book on the subject. In order to provide the reader a basis for understanding the system, the author presents a background of resource management, a brief discussion of forest management, an explanation of multiple-use, a discussion of his concept of multipurpose *management and the applicability of multipurpose management to water resource projects.*

This philosophy of forest resource management was developed almost a decade ago in an effort to provide an avenue of communication to planners and resource developers who were not trained in the field of natural resources management. This was the era before widespread concern with ecology and the environment. It was the time prior to passage of the National Environmental Policy Act (NEPA), which has changed national resource management policies.

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The impetus to develop the system came as the result of the preparation of a plan for management of forest resources associated with a particular reservoir project. However, the approach was not considered "traditional" and was rejected without trial. Now that there is greater empathy and concern for the environment, the author is again proposing the system as a technique for management of forest resources associated with water resource projects.

The term "Harnessing the Habitat" will likely evoke a variety of emotions, perhaps considerable consternation, according to the convictions of the reader. If so, it will serve the purpose of opening minds to the consideration of a more holistic attitude toward resource management in general and forest management in particular. All too frequently there is a tendency to neatly categorize philosophies and activities into very constrained, but comfortable, arrangements or compartments. The attitude of "don't rock the boat" and what I will term "professional provincialism" reigns. The latter term is that which I use to describe the attitude that intrusion into an academically defined field of specialization is not to be condoned, even though the "intruder" is qualified through training or experience. This attitude, which is beginning to relax, has fostered tunnel-vision and frequently constrained development of a holistic approach to planning and management of resources. The author prefers the admonition of Peter the Great, who once stated, "Follow not the system as the blind man followeth the wall."

Resource Management and Conservation

A time-honored adage decrees that "The land and its resources belong to many men—some who have passed from this life; many now living; and many more yet to be born." It is also axiomatic that "Resource stewardship is the rent that we pay for the space we occupy while on our journey through this life."

The concepts of resource management and conservation are not new. Many advocates of resource management have presented their philosophies throughout the ages. Very early in history men such as Plato and Cicero wrote discourses on the subject. In more recent times Gifford Pinchot and Teddy Roosevelt gave a new meaning to the term "conservation" when they defined it as "wise use" of natural resources and emphasized the policy of management for "the greatest good for the greatest number in the long run." Aldo Leopold wrote of the need for mankind to embrace a "land ethic." Generally these admonitions fell on deaf ears as the concepts of economic growth, development of resources (actually more exploitation than development), and the "myth of superabundance" became our guiding policies and philosophies. However, the present generation has finally come to realize that natural resources are not inexhaustible and management of these resources is essential. This awareness has become particularly acute during the past decade, and as a direct result, laws have been enacted, resource management programs have been overhauled, and conservation is finally beginning to receive some long overdue attention.

I once heard the term "conservation" described as "taking care of where we live, what we wear, what we eat, and what we drink—all of what we have—because if we don't, we won't." Based upon mankind's track record of resource management, it is obvious that good intentions and rhetoric—regardless of how often repeated through the ages—will not solve the problem of conserving our dwindling supply of nonrenewable natural resources nor the urgent need for improved management techniques applicable to our renewable resources. Also, it is necessary to maintain a proper perspective in regard to resource management.

The only logical reason for the conservation of our natural resources is for the conservation of our human resources—you and I. In the author's opinion, conservation or preservation of any non-human resource solely for the sake of that resource itself is not necessarily justified. The conservation or preservation of natural resources should be oriented toward their ultimate value and use to man.

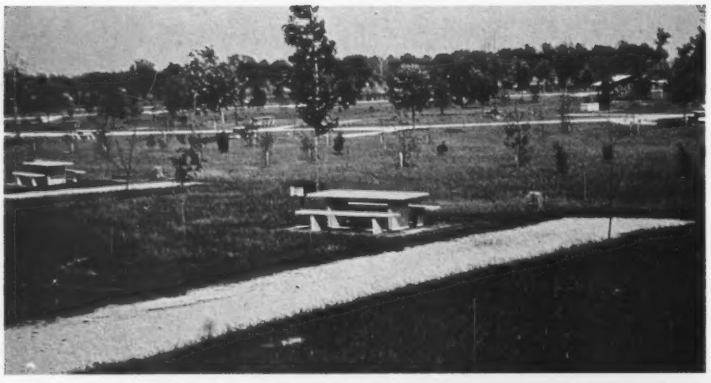
However, it should not be inferred that we have the right to arbitrarily and capriciously squander our natural resources. It is the past attitudes of human greed and disregard for future consequences which have created our current resources problems. In planning for our immediate resource needs we have a responsibility to assure that our actions do not foreclose the options for potential changes in resource needs or changes in resource management attitudes of future generations. Since we do not know what changes in attitudes, technology, or society will frame the future, it is difficult to project resource plans even ten years hence with any degree of certainty. And what about the next century? Or beyond? Tunnel-vision and shortsighted planning in a vacuum, coupled with professional provincialism, are luxuries which we can no longer afford. It is time to apply the concepts of a "land ethic," "resource stewardship," and holistic multipurpose management.

Scope of Forest Management

Since this article is concerned with the management of forest resources, it is necessary to briefly discuss the scope of that subject. The spectrum of what constitutes forest management has differed with various cultures and generations. In this country it has usually been associated with actions related to the harvesting of mature stands of timber and with fire protection. However, forest management is much broader than that in scope and encompasses the management of many types of land where woody vegetation is dominant. It also includes the management of certain types of open areas associated with forested areas.

Since most of the land on this planet is capable of supporting woody vegetation, the potential for

This typical "landscape area" offers a broad vista into the distance; its aesthetic value is unquestioned.



A camping area that fits into the category of "outdoor recreation area." It is in need of screening (protection) and habitat value plant materials.

forest management is quite extensive. For example, according to the U.S. Forest Service, forest land is classified as land which is capable of growing commercial timber and is at least ten percent stocked. Many areas not usually considered to be forest lands would meet these criteria. For instance, most urban habitats would qualify as "forest land." In fact, when considering the amount of vegetation growing in most urban areas, we might ask the question whether the area is an urban area with associated tree cover or whether it is a forest area with associated man-made structures, functioning as a temporary disclimax.

Furthermore, urban forestry has been an active pursuit in many parts of our nation since the time of its founding. In the past professional provincialism has frequently suppressed the thought that management of this vegetation was within the purview of forest management. Recent developments, such as the founding of the Pinchot Institute and recognition of urban forestry by the Society of American Foresters, has begun to provide some cognizance for this facet of forest management.

Forest management, from the author's viewpoint, involves any site which supports, or is capable of supporting, arboreal vegetation, along with any associated areas. Sites may range from a very minute habitat, consisting of only a single tree or shrub and its environs, to an extensive wilderness area, and includes every conceivable habitat condition between these extremes.

Multiple-Use Forest Management

Multiple-use forest management for sustained yield is the philosophy which has governed the management of our National Forests for many years and is the guiding philosophy of other forest management areas, both public and private, where enlightened resource management is practiced. The concept of multiple-use infers that it is possible to manage forest lands simultaneously for more than a single purpose. Usually, one use is dominant and other compatible uses are secondary or tertiary. Multiple-use does not mean that several, or more, uses are undertaken on every acre of a forest management compartment at the same time, but that these uses may occur as single-uses on various different acres within the compartment. Multiple-use forest management is concerned with optimizing the *present* uses of forest resources.

Multipurpose Forest Management

The system of multipurpose forest management, as proposed by the author, is based upon the philosophy of multiple-use management, but expands upon that concept. While multiple-use forest management is concerned with optimizing present, or existing, use of forest resources, multipurpose forest management is concerned with *both* the *present* and *potential* uses of forest resources. It stresses the application of resource management techniques which will fulfill present needs, while providing for possible potential changes in management emphasis or needs. This system provides the opportunity for future generations to choose a course of management which may differ from the current course of action.

The techniques of management include (1) classification of all sites into one of eight primary management categories; (2) determination of existing vegetation; (3) determination of site capabilities to support other species not present; (4) rating of the various existing and potential species according to each of five resource management values; and (5) preparation of forest management prescriptions which will optimize present multiple-use aspects of the area, and also will provide direction for development of habitat conditions which will be potentially convertible to other uses, if necessary or desired, constrained *only* by the capability of the site. These prescriptions are prepared for management

compartments. Classified according to one of the eight management categories, they may be subdivided into zones which are oriented toward management objectives of another category, as is the case in multiple-use management.

All management compartments are classified according to one of the following eight primary management categories, which provide the basis for management prescriptions. These categories were chosen because they seem to fit all presently determinable forest management objectives. This hierarchal structure will be revised, if necessary, to meet changing conditions.

Descriptions of the eight primary forest management categories are as follows:

■ *Preservation areas*—Management of these areas is directed toward the preservation of existing conditions. They usually contain vegetation resources which are considered unique, rare, or worthy of particular protection from exploitation. These areas, such as the redwood stands of northern California, for example, are intended primarily as single-use areas.

■ *Wildland area*—Two classes of land fit in this category. The first would be exemplified by a tract of wilderness, such as might be found in the National Park system or in a National Forest, which is managed primarily for retention of its particular wilderness values. Management practices may be required to avoid site deterioration and ultimate deterioration of wilderness values. Another class of land in this category is that of "wild" land. Lands in this class are similar to wilderness lands but are smaller in acreage; management objectives are similar.

■ *Protection area*—Lands in this category serve the primary purpose of providing protection of a specific resource or of another use area. Examples are uses of vegetation for protecting soil from erosion, protecting a watershed, and providing windbreak or shelterbelt protection. Management practices aim toward maintaining a continuous vegetative cover, composed of species suited to the particular need. Multiple-use management is feasible on these areas.

■ *Habitat areas*—This group comprises a wide variety of areas, all with the prime function of providing suitable habitat conditions for either man or wildlife, or both. The types of sites involved may range from an individual homesite for human habitation to large wildlife management areas. Usually, several other secondary uses are possible and compatible.

■ *Outdoor recreation areas*—These areas provide a suitable environment for the pursuit of outdoor recreation activities. Although they are usually thought of as being single-purpose, frequently it is possible to serve several other uses, e.g., wildlife habitat, protection of forest products.

■ *Landscape areas*—Lands in this category are managed primarily for their aesthetic values. Multiple-use management is applicable. Virginia's Skyline Drive is an example of such an area.

■ *Product areas*—This is the category of lands usually associated with the practice of forestry, since the primary management objective is the production of some form of forest product—usually sawlogs or pulpwood. Multiple-use management is generally possible. Product areas are widespread throughout the United States on both government-owned and private forest lands.

■ *Scientific areas*—Lands in this category are managed primarily as research or demonstration areas, and serve to provide information for improving management techniques or learning more about forest ecosystems. The numerous Forest Service research areas are typical. Such lands may also serve as outdoor laboratories for students or other compatible uses.

All species of vegetation *capable* of growing on a specific site for which a prescription is being prepared are considered for use, rather than considering only the *existing*

This is a potential wildland area, protection area, habitat area, or even products area.

"Scientific areas" have near equal value factors for outdoor laboratories and wildlife habitat areas.

vegetation. These species are rated according to their values for each of the following purposes:

- Products—*the value factor for producing useful commercial, or non-commercial, products.*
- Aesthetics—*the value factor of characteristics or qualities of vegetation which provide a pleasing appearance, color, form, odor, or other elements pleasing to the human senses.*
- Wildlife Habitat—*the value factor of the capability of a species of plant to provide the essential needs of food, nesting, or cover for wildlife.*
- Protection—*This value varies according to the type of protection afforded and generally is related the physiognomic characteristics of species, although other characteristics may be involved.*
- Environmental—*This value represents plant characteristics not included in the above categories but still of use in the overall environmental schematic.*

All species of woody plants which are suited to a specific set of environmental conditions on a designated use area should be rated according to their various values of a 5-unit numerical scale. The lowest rating (1) denotes a very low, or negative, value; the highest rating (5) then denotes a very high, or exceptional value; other ratings are intermediate. It is important that *each species be rated according to its value in each of the five value categories.* Those plant forms which have medium to high values in three or more categories represent the most valuable species, and are known as "multi-value" species. The rating value for each species is multiplied by a weighting factor, to be determined as appropriate, which will reflect the *present* primary, secondary, tertiary, etc. management objectives for a specific compartment, or zone. This will assure that present multiple-use needs are satisfied.

A primary objective of multipurpose forest management is the creation and development of habitats which are composed of combinations of the highest multi-value species suited to the primary management purpose of the area, capable of maintaining a naturalistic ecosystem, and providing for future flexibility by leaving all potential options open.

Application of Multipurpose Management to Water Resource Projects

The development of water resources projects presents a unique and future-oriented opportunity to practice a very intensive degree of resource management—because of the "high use" values involved. The degree of resource management intensity is usually closely related to the expected return—in either tangible or intangible use benefits—on the investment.

Most water resource projects attract heavy use, and, by their very nature, provide an opportunity to generate a variety of benefits. Although such projects were once considered to be limited to development to serve a single purpose, e.g., water supply or flood control, they are now being developed to derive multipurpose benefits. Wherever it is possible to develop these projects in a manner which will optimize their various resource values, consistent with existing laws and regulations, such management would seem to be in the best public interest and should be encouraged.

Frequently project development and operation requires acquisition of large acreages of land. Often much of this land is inundated, as in the instance of reservoir construction, but usually a substantial amount of project land remains available for management of terrestrial resources. At present the terrestrial portions of a project are usually planned for use for outdoor recreation or wildlife habitat. These certainly are beneficial uses, but they are not necessarily the exclusive present or potential use. The valve of this terrestrial habitat is directly related to the values as-

A multipurpose area in the truest sense of the word.

sociated with specific areas. These values generally equate to type, quantity, composition and distribution of the vegetative cover, particularly woody vegetation.

Management purposes for lands associated with water resource projects generally fall into one of four general use classes, as follows: (1) administration and operation, (2) outdoor recreation, (3) wildlife habitat, and (4) miscellaneous or unclassified.

The application of the principles of *multipurpose* forest management on water resource project lands—as opposed to the traditional concept of *multiple-use* management—presents an infinite array of advantages. Some of the possible scenarios are illustrated here to demonstrate the methodology involved.

Administrative Use Areas: Lands in this class would generally be categorized as "habitat areas." The primary management concern would be the development of a suitable environment which was aesthetically pleasing.

Outdoor Recreation Use Areas: These areas generally would be classed in the "outdoor recreation area" category, but could fall into one of three sub-classes, namely (1) camping, (2) picnicking, and (3) general recreation use.

In camping use areas management prescriptions would consider first the aesthetic and screening (protection) values of species suited to the site. Wildlife values would receive secondary consideration, because it is quite feasible to have a recreation use area where forest products harvesting is a use along with recreation. This occurs in management areas in both Europe and this country at the present time.

In picnic areas and similar use areas, the primary emphasis on species values would be that of aesthetics, wildlife, and general environmental values. Values for products or protection would not generally carry much importance.

In general recreation use areas the ranking of values would probably be products and wildlife values first, followed by general environmental values.

Wildlife Habitat Use Areas: Lands classified for this use should be developed with plant communities consisting of species with the highest wildlife values, with product values next in importance. Other values would not generally be significant.

Miscellaneous (Unclassified) Use Areas: Some areas on water resource project lands are not designated for any particular purpose. On these areas it seems best to promote development of stands of the best multi-value species which are adapted to the sites. Then future choices can be oriented toward any type of use desired. Also, it would be useful to develop extensive-use nature trails, buffer zones, or similar areas on non-designated use lands. There are other types of development, such as interpretive areas, prairie areas (in appropriate locations), and arboreta, all of which are compatible with the use of project lands and which would greatly improve their usefulness to the present and future publics.

The scenarios presented are necessarily very generalized, and specific management prescriptions should be prepared only after conduct of an adequate inventory and analysis of all essential site conditions and evaluation of management objectives. However, it is important to recognize that the acreage of land available for use is finite and our standard of living will depend upon how it is managed. All lands associated with water resource projects are part of the nation's heritage and should be managed for optimum, rather than "adequate," multipurpose use.

Application of sound, multipurpose resource management practices, as outlined above, will indicate to future generations that this nation took heed of the need for better resource management to serve its immediate requirements, while giving due consideration to the needs of those who are yet to be born. These practices will also optimize the present and potential resource values of our finite land acreage and show that stewardship is more than rhetoric, that it is an intergral part of water resource project planning and management. ■

The author proposes that forest land classifiers look beyond existing vegetative cover and determine what the land is capable of producing.

Short Takes...

A Harbor of History

by **John C. Fine**

Scores of old ship hulks have lain amouldering in New York Harbor, forgotten and unmourned, until the U.S. Army Corps of Engineers and the State of New Jersey recently teamed up to reclaim the marshland on Liberty Island for the establishment of a state recreational park.

Perhaps it was America's 200th birthday, a renewed interest in preserving the few remaining links with her maritime history, or the foresight of a few conscientious men—whatever, there is now hope that these gallant ladies of the harbor can be spared the ignominy of being dumped into some nameless landfill or suffering an ungallant burning at sea.

Known internationally for his discovery of early Greek shipwrecks in the Mediterranean and long association with the University of Pennsylvania's Department of Archeology, Dr. Peter Throckmorton was asked to take on the job of assessing, documenting, and preserving selected rotting ships of historical importance, by the New York District of the Corps.

"There are thousands of wrecks around New York Harbor," Throckmorton says, pointing out two "watermelon" barges he was trying to save from imminent destruction by the wrecking crane working nearby. Dr. Ira Abrams, a colleague from Pennsylvania, concurred.

The two men planned to set up an amateur, volunteer effort to help survey and classify the shipwrecks, and then to excavate the more significant ones.

"It's amazing," Throckmorton reflects, describing his involvement with the project. "We started with a borrowed desk in the World Trade Center, and now we have an office in the Brooklyn Museum, with the possibility for storage space. What I should be doing in the next year, Ira and I and others, is learning every wreck in the harbor. I am an archeologist, and I like to work on ships."

And ships there are. Scores of them, from tugs to barges; from schooners and lighters to steamers and canal boats of every shape and description. Some sunk, some rotting in the mud—awaiting discovery by this eager team of scientists and the volunteers they hope to recruit through sponsoring organizations such as the South Street Seaport Museum and the National Maritime Historical Society.

Planning for the Liberty Island State Park began several years ago. The Corps of Engineers became involved when New Jersey took advantage of a cost sharing program operated by the Federal government. Work began under a Federal grant that provides two-thirds of the funds, with the state putting up the rest. The project is aimed, primarily, at removing the sources of debris in New York Harbor. Historical salvage is icing on the cake.

Approximately $1 million has been allocated to clean up the first increment outlined by the Park Project. The Corps of Engineers has jurisdiction over everything from the high water mark on, with the State responsible for everything up to the high water. This leaves the Corps to deal with derelict vessels, piers, underwater obstructions and submerged shipwrecks. It is also the Corps' responsibility to conduct an environmental impact assessment of the productive marshland surrounding the project site.

"It doesn't look like much now, but when we clean up the debris, it will be a nice place for people to visit and examine the flora and fauna," says Dr. Simeon Hook of the Corps. "In fact, we found canvasback ducks in the marsh and a surprising assortment of benthic life that we want to preserve," he added, pointing out over a verdant marshland and nearby flats. A bulldozer worked in the distance, clearing away rotted timbers from an abandoned barge.

As part of the environmental impact study, the Corps undertook a cultural resources evaluation to determine the impact the project has on any cultural or historical resources. It was in this area that the ship archeology became a factor.

The Corps commissioned an overall archeological study of the area. Every vessel and derelict was marked and located, and side scan radar was used to pinpoint underwater wrecks. The study revealed that 98 percent of the vessels were valueless post-World War II barges, and that only 11 bore enough promise for more intense investigation.

An old fishing vessel, abandoned and rotting, lies at its final anchorage near Coney Island. Photos by the author

Mr. Fine is a New York State attorney at law.

Throckmorton and colleague Norman Brower sorted through the 11 recommendations, eventually narrowing the list to three above water derelicts and four submerged. Four dives were made on the underwater wrecks, and nothing of significance was discovered.

"Two of the above water wrecks are watermelon barges," according to Throckmorton, "not because they carried watermelons—but because they are shaped like them. They were made in the 1850s; actually rebuilt on the hull of another type of vessel.

"The third ship was tentatively classified as the NEWTON, a World War I wooden cargo steamer that was used as a Navy training vessel. If it proves to be the NEWTON, then it's the last of its class of vessel in existence."

One wonders how a ship like the NEWTON, one of 560 Ferris-type steamers built, could have been forgotten, abandoned in the mud. Perhaps after the war, with a peacetime Navy cutting back, burdened with an elderly wood steamer, it follows that she was left to decay on the Jersey shore, a few hundred yards from the Statue of Liberty. Aerial photographs of the harbor, found in the archives by Dr. Hook, show what appears to be the hulk of the NEWTON in place behind Liberty Island, when Navy records show her in commission. This throws the whole identification into controversy. Perhaps the hulk was a Ferris prototype . . . The scientists are not sure.

Unfortunately, no real documentation can be found on the three. Plans have been made to have draftsmen make drawings, and in this manner get some idea of what the ships looked like in their heyday. This will provide a permanent record of the ships before they are removed.

Old ships may not be the only thing Throckmorton and crew will locate in the harbor. Stories of buried pirate loot and sunken treasure ships have been traded since archeologists began diving there. It is historical fact that the notorious Captain William Kidd was once hired to protect New York from pirates. His ship, the ADVENTURE GALLEY, was so successful that he decided to go into the pirate business himself. Folklore has it that some of Kidd's booty lies in the Hudson River off Peeksville, N.Y.

Other maritime records reveal that the HUSSAR, a 28-gun British frigate laden with $4 million in silver-payroll for British soldiers in the American Revolution—sank off Hell Gate on Nov. 23, 1780. Parts of the HUSSAR were found in 1811, but no one has yet succeeded in locating her treasure.

Harbor watchers and photo buffs can find ample evidence of America's history among the reeds and shallows of many of New York City's canals and bays. When Lake Erie was connected with the Hudson waterway by a 40-foot wide, 326-mile long ditch in 1825, New York City burgeoned with the midwestern grain trade, and saw a plunge in price from $100 to $6 a ton. The seaport harbor of New York boomed as stocks of cheap grain surged across the ocean to European ports. To handle this great commerce, more than 4,000 canal boats were built, in all shapes and sizes.

These barges moored at Coenties Slip at the end of South Street in Manhattan as the canal trade flourished in the mid- and late-1800s. Eventually steam power boats and the New York Central Railroad took the measure of the wooden canal barges, and most were burned to salvage their fittings, or abandoned to rot. Canal boats lie about New York and Jersey shores, forgotten, abandoned pieces of maritime Americana.

It was only a hundred years ago that the Port of New York was visited by 1,074 steamers, 1,451 schooners, 1,076 brigs, 2,234 barks and 389 full-rigged ships. Hardly surprising to the New Yorker that saw the gala parade of "Tall Ships" under sail up the Hudson on July 4th, 1976, perhaps.

Archeologist Peter Throckmorton shows a hulk believed to be that of the NEWTON–a World War I era wooden Navy training vessel. If so, it's the last of its kind in the world.

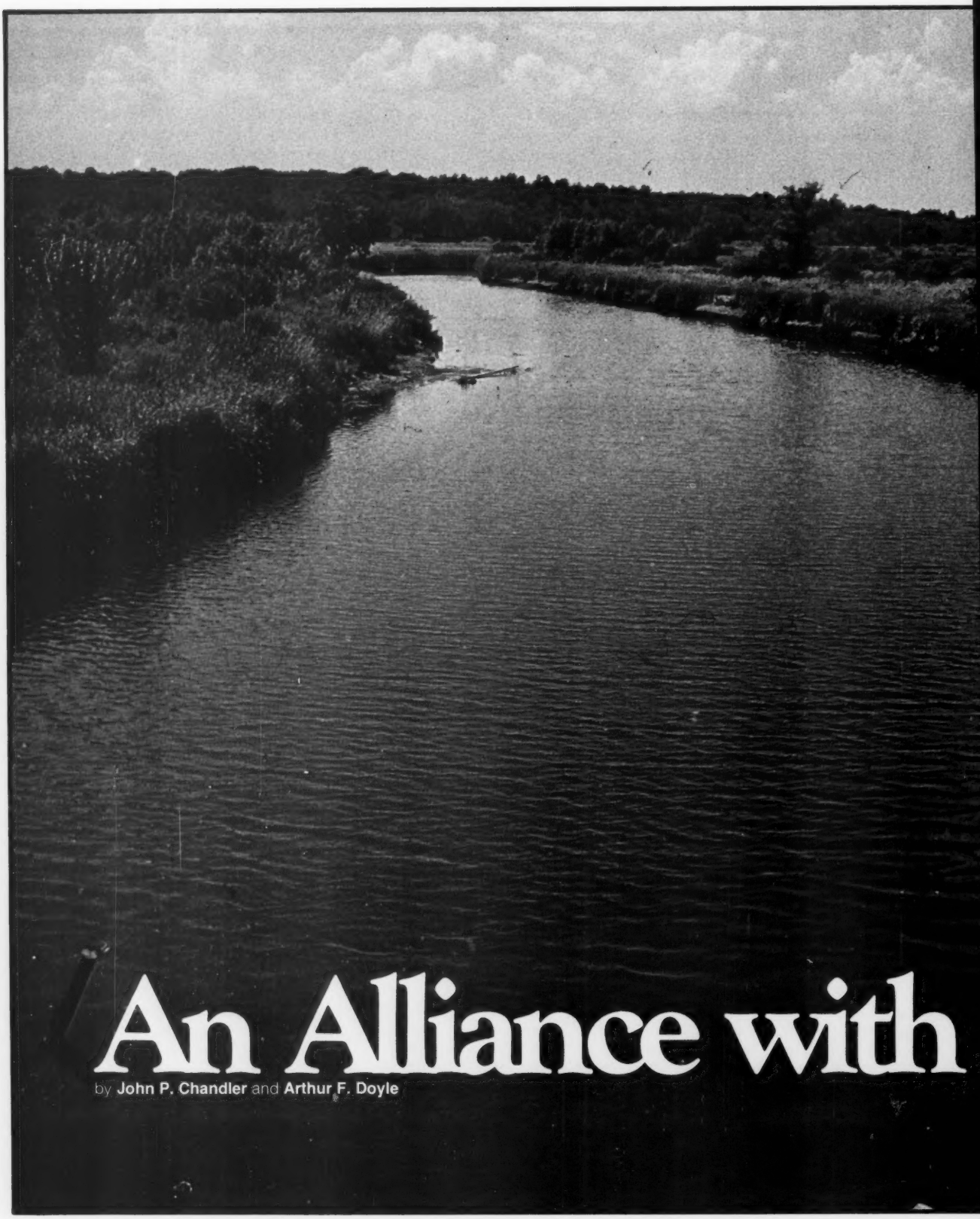
In 1916, an explosion shook the entire Liberty Island area, when a German spy successfully sabotaged a munition depot. The Black Tom explosion and subsequent fire destroyed many vessels along the shore, creating the marshlands which are now part of the State Park area. Corps officials have called in Navy demolition consultants, since it is believed that some of the sunken vessels may still contain unexploded ammunition. The likelihood is that the munitions should have fully disintegrated during the ensuing 60 years, but contractors have been alerted to use caution should such material surface.

There is plenty of such history beneath the fouled, murky waters in the countless bays, lagoons and back canals off New York Harbor.

And unsettling moments . . .

When Throckmorton was preparing for newsmen to photograph him jumping into the harbor, in a symbolic first dive over the submerged wrecks, he wanted everything to go just right. In order not to disappoint the reporters, he carefully pre-positioned artifacts underwater so that he could reappear on the surface with something camera-worthy. The trouble was, the water was so murky when he made his dive—in full view of a dozen camera lenses—that he was unable to find the "treasure" he had secreted!

A beneficial effect of the pollution of the harbor is that the teredo worm, a small mollusk that bores into the submerged wood of a ship's planking, cannot live there. As a consequence, the underwater hulls have been preserved almost intact. ■



An Alliance with

by **John P. Chandler** and **Arthur F. Doyle**

During major storms, upper basin wetlands adjacent to streams act as sponges, absorbing overflowing waters and thereby reducing flood levels downstream. The fact that marshes can alleviate flooding has long been recognized, but that knowledge has played little part in flood control planning. Then, in the late 1960s, events in eastern Massachusetts combined to produce an alliance of men and the natural environment that may become a prototype of nonstructural flood control projects. The program, currently being implemented by the U.S. Army Corps of Engineers, New England Division (NED), is the Charles River Natural Valley Storage (NVS) Project.

NVS began routinely enough with a standard feasibility study of ways to protect flood-prone areas of Boston and Cambridge in the lower Charles basin. In recent years this area has been subject to severe flooding; the record flood of August 1955 caused damages estimated at $5.5 million. In 1965 Congress directed the Corps to examine ways to control flood damages in the urbanized lower basin and to head off any significant flood damages in the urbanizing middle and upper portions.

The watershed that the New England Division team set out to study is shaped like an hourglass. It is about 15 miles wide and only 31 miles long, yet the Charles River travels 80 miles from its headwaters at Hopkinton, Massachusetts, to its terminus in Boston Harbor. The Algonquin Indians' name for it was *Quinobequin,* which means meandering.

Nearly 10 percent of this basin is still covered by wetlands, primarily in the upper and middle sections. The middle Charles basin contains established suburban communities, while the character of the upper portion is rapidly changing from rural to suburban. By contrast, nearly all the marshes in the lower watershed have been replaced by high rise office buildings, universities, apartment complexes and parkways.

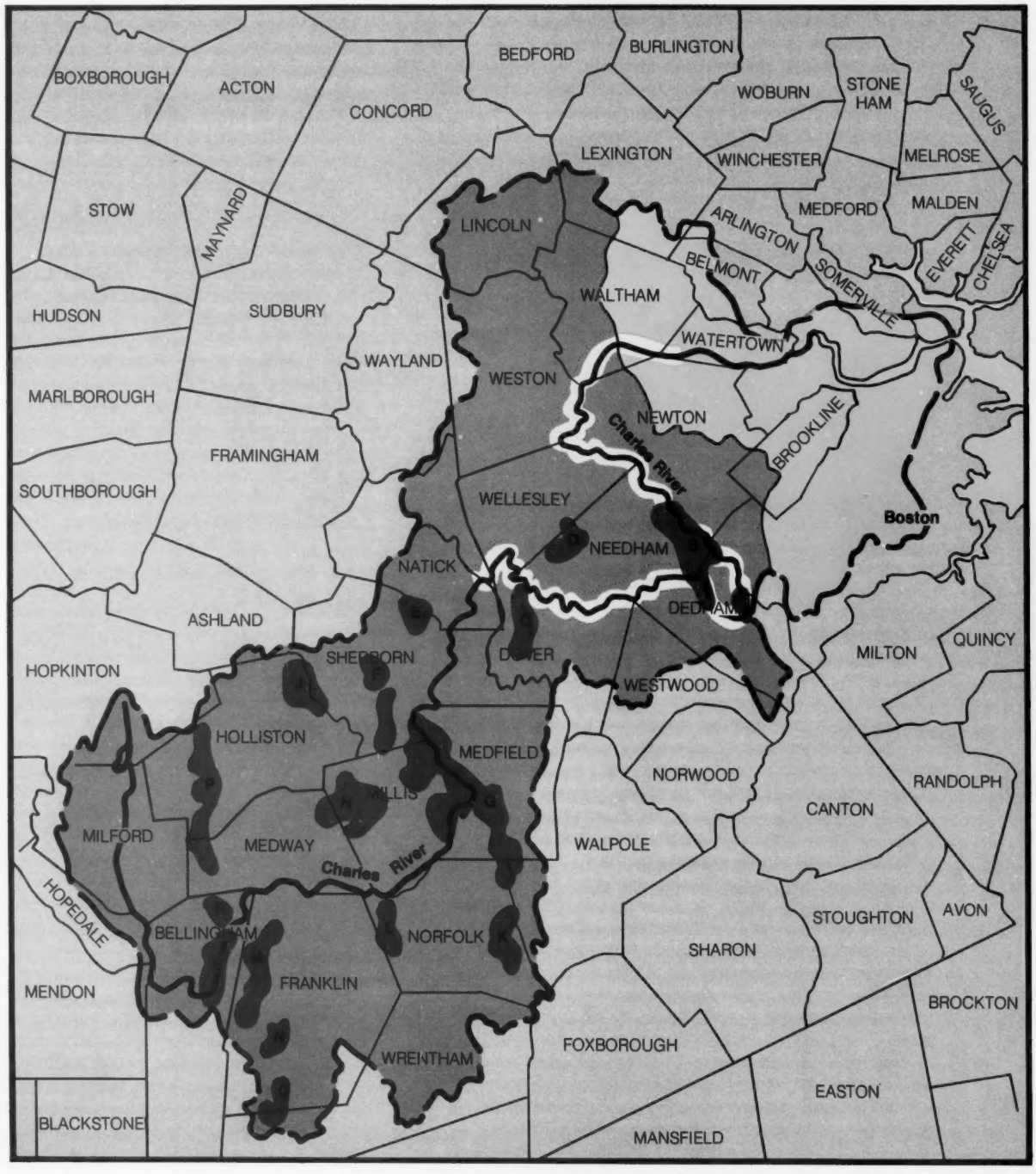
Near the river's mouth is an impoundment created by a dam built in 1910. The flooding in the lower Charles occurs when a major storm hits the watershed and the accompanying high tides impede the river's flow into the Harbor, causing the impounded waters to back up and overflow. The situation is aggravated, of course, by the storm runoff that races across the hard-topped surfaces of Boston and Cambridge straight into the Charles River.

The first part of the Corps' study dealt with the lower basin flooding and was finished in 1968. NED issued an interim report that recommended construction of a new and more effective dam with facilities that could pump storm water out against the high tides. (This new structure, located about a half mile downstream from the old dam, has now been completed.)

Just as the NED team was finishing this part of the study, a major storm hit the watershed. The flood it spawned approximated eastern Massachusetts' 1955 flood of record and gave the team a rare opportunity to field-test their growing conviction that the basin's system of

Colonel Chandler is the Division Engineer at New England Division, U.S. Army Corps of Engineers, at Waltham, Mass. Mr. Doyle, project engineer, has managed NVS from its beginning.

Figure 1. Acquisition priorities for the 8,500 acres are based on area location, volume of storage capacity and degree of encroachment threat. Areas G, H, K and L form the top priority group because they are at the geographic center of the project, they contain the largest storage capacity with 47 percent of the NVS total, and they are in the greatest danger of development. Second in priority are areas B, C, D and E, while areas M through S are third. Purchase of areas, F, I and J in 1980 will finish the acquisition phase.



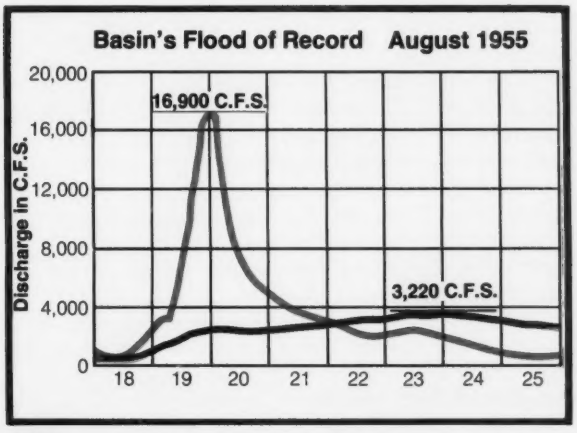


Figure 2. The hydrographs compare discharges at Charles River Village with the adjacent Blackstone River as measured at a USGS gage only 20 miles from the Village. The Blackstone River line illustrates the flood runoff characteristics of most of the inland New England rivers while the Charles River line vividly demonstrates the tremendous effect of the natural valley storage that is found on some of the coastal streams. At Northbridge, 29 percent of the flood volume on the Blackstone ran off the first day and 30 percent on the second for a total of nearly 60 percent in 2 days. The entire flood had substantially passed in a week. At Charles River Village about 4 percent ran off the first day and 6 percent on the second for a total of 10 percent in 2 days. It took a week to pass 50 percent of the flood and approximately a month to pass the total runoff.

scattered, undeveloped wetlands was acting as an effective flood control mechanism. That conviction was based on records of earlier storms which showed extensive damages in the lower basin but relatively minor damages in the middle and upper portions.

A Corps reconnaissance team began commuting to the upper and middle wetlands to observe reaction to the near record storm. The 1968 flood crest moved so slowly that the team was able to measure the crest one day, go home for the night, then come back the next morning to pick it up slightly below the point where they had left it. While runoff from the 58-square mile lower basin crested at the old dam in a few hours, the upstream peak took 4 days and the entire volume of storm water took a month to reach the structure. About 50,000 acre-feet of storm water—the equivalent of an average Corps reservoir in New England—had been stored somewhere.

This behavior resembled that of the 1955 flood, and the reconnaissance team could actually see the natural reservoir's function—first holding back the floodwaters and then gradually releasing them. It was this retarded flood that was keeping residents of the upper and middle Charles basin safe and dry. A natural system was performing in a remarkably effective manner.

On their reconnaissance trips, the study team travelled on the sub-base of I-495, then under construction. Boston's second circumferential highway, I-495 runs across the upper watershed, opening this rural area to accelerating development. The potential for rapid development gave a sense of urgency to the team's work. Further urbanization would threaten the natural reservoirs by reducing their total acreage and storage capacity. In addition, as urbanization spread and pavements and drainage systems replaced vegetation-covered land, storm runoffs would become more intense and the land's water storage capacity would be exceeded. This unchecked momentum of grozth would increase upstream flood damages and threaten the safety of downstream residents.

Recognizing the value of this natural flood control system was, of course, only the first step. The study team next had to find ways to ensure its survival.

During the latter part of the study all standard approaches to flood control were examined. If no action were taken, it was estimated, in 30 to 40 years $100 million would be required for flood control structures. It was generally agreed that any of the traditional flood control measures would be aesthetically undesirable and that costs would be out of proportion to benefits. (The Corps will not recommend a project to Congress unless its benefits—the savings that would accrue to people and communities formerly affected by floods—would outweigh its construction, operation and maintenance costs.) The study team estimated, for example, that channelizing a

Natural valley storage in upper watershed is shown at time of normal summer flow and while storing floodwaters.

10-mile stretch of the Charles would cost $30 million, exclusive of social and environmental costs.

A land acquisition program seemed the best solution to the watershed's growing problem—and the sooner this was accomplished the better. Recent studies had showed that Massachusetts was losing its wetlands at the rate of one percent a year, and the Boston metropolitan area, at twice that rate. Projecting this loss rate into the future, the Corps anticipated that about half the storage of the wetlands in the Charles River basin would be gone within 30 years.

About 20,000 acres of wetlands remained in the basin in parcels that varied in size from a few to more than 2,000 acres. Obviously, Federal acquisition of all these acres would be impractical. Although the Corps could take the lead by conserving the most critical sites, a combination of Federal and non-Federal actions would eventually be necessary to safeguard the open space.

Elliot Childs, then Chief of the Corps Hydrology Branch and a basin resident thoroughly familiar with the wetlands, studied the extent and the location of critical areas. One hundred acres was selected as the minimum size that would be practical to manage. Smaller areas are less valuable because the smaller an area, the shallower it is, and the storage capacity per unit of surface area is proportionately less. Childs found that approximately 10,000 acres, about half of the total wetlands, had major floodwater retention capabilities. Geographically, these areas are separate units widely distributed through the watershed. Hydrologically, however they act as a single integrated system.

In 1965, Congress directed the Corps to examine ways to control flood damages in the urbanized lower basin and to head off significant flood damages from encroachment, as shown here, in the mid and upper portions. NVS was conceived during the subsequent planning study.

Authors were presented with plaque for the New England Division after the NVS project took top honors in the Corps of Engineers 1977 Environmental Award Competition.

To minimize the unit cost of acquisition, each parcel was inspected by a real estate appraiser and an engineer to determine the practicality and feasibility of its purchase. Subsequently, the initial 10,000-acre goal was reduced to about 8,500. New development had reduced some parcels to fewer than 1000 acres, limiting their retention capacity. Extreme backs of lots were also dropped since their purchase would not be feasible on the basis of cost per acre–foot of storage.

While the real estate division was appraising the costs of an acquisition program, Corps economists were developing estimates of benefits. The all important benefit-cost ratio was found to be favorable.

The final recommendation called for Federal acquisition of lands or easements in 17 natural valley storage areas. These range in size from 118 acres to 2,340 acres. Only three are adjacent to the Charles; the others are located in tributary sub-basins.

Meanwhile, communication lines were kept open to the 16 towns and cities situated in the wetlands areas. For example, interim memos and tabloids have been distributed regularly since the late 1960s to keep local residents up-to-date on NVS.

In 1966 two committees were established which assisted the Corps through 1971. The Coordinating Committee, made up of Federal, state and regional representatives, guided and coordinated technical aspects of plan formulation. A Citizen Advisory Committee consisting of more than 30 representatives of local communities as well as industrial, conservation, education, recreation and real estate interests acted as a liaison with the general public. They passed on to the Corps the wishes of interested persons and organizations and served as a sounding board for study proposals.

Four formal public meetings have been held—three early in the study in 1966 and one at the study's conclusion in 1971. Before the last meeting, the Citizen Advisory Committee sponsored a series of 12 meetings in different communities to pass on detailed information about the plan. More than 600 persons attended. Those attending the 1971 public meeting unanimously endorsed the plan.

While the proposal was being processed by the Executive Branch, the U.S. Congress became interested. With annual flood losses climbing steadily across the country, the Federal government was besieged with pleas for physical and fiscal bailing out. The public participation effort carried on through the 5-year planning phase created the momentum to generate interest on Capitol Hill. The 30-person Citizen Advisory Committee and the organizations its members represented visited and wrote to members of Congress and anyone else who might be helpful. The response was enthusiastic. The Massachusetts delegation to Congress became fully committed to NVS, and in October 1973 the Massachusetts legislature passed resolutions supporting it. Finally, the word came from Washington that the Water Resources Development Act of 1974 contained authorization for the project. Six years after its conception, the idea had become law.

Recently completed dam on lower Charles was the other element of a flood management plan for the entire basin. This traditional approach was followed to protect heavily developed areas from recurring flood losses.

The March 1974 authorization and funding by Congress initiated NED's next step, the advance engineering and design phase. From November 1974 to December 1977 the specifics of the project were worked out. The basin's record flood of 1955 and the Standard Project Flood—a hypothetical flood used by the Corps as a measure of flood potential—were delineated on aerial maps of the marshes. The actual land-taking line for each storage area was established somewhere between the two flood limits, depending on the configuration of the individual tracts of land.

Acquisition procedures and priorities were also developed during this intermediate phase. While hydrologists were measuring storage capacities and engineers were determining boundaries, real estate personnel were identifying the more than 500 ownerships, searching titles, appraising and negotiating for properties. A great deal of this work was contracted out to qualified local appraisers.

In accordance with law, the Corps will pay fair market value for lands acquired for public purposes. Fair market value is generally defined as the price that a knowledgeable buyer willing, but not obligated to buy would pay to a knowledgeable seller willing, but not obligated to sell—for lands acquired for the public good.

Some owners are unwilling to sell their land even though they support the NVS program. In other cases critical wetlands are owned by land trusts such as the Massachusetts Audubon Society. A special restrictive easement has been prepared for these situations. It allows the owner to retain title to the land and to use it in ways that do not conflict with the flood control function and it gives the government access for inspections and the right to preserve the land in its natural state. In cases of price disagreement or clouded titles, NED may have to institute eminent domain proceedings.

NED purchased the first acreage in May 1977, soon after Congress appropriated the necessary funds, and completion of acquisition is scheduled for 1980. The Federal government is paying for 100 percent of the $10-million acquisition program. Also in 1977, the Massachusetts legislature authorized the State Water Resources Commission to establish encroachment lines on non-NVS flood plains in the watershed and gave the state Department of Environmental Management jurisdiction in those lands.

Once in the public domain, the 8,500 acres will be managed in a manner consistent with its natural flood control purpose. The Corps will retain ownership but prefers that a local or state organization assume responsibility for its management. A two-tiered management committee has been established to recommend types of recreational activities to be permitted. The first tier sets policy guidelines, while the second deals with specific programs for specific areas.

The Metropolitan Area Planning Council, with a representative from each of the 16 communities, was engaged to chair the policy unit. During the past winter the Council held meetings with various town officials interested in wetlands management. The Council's final report had the concurrence of all the affected towns and cities.

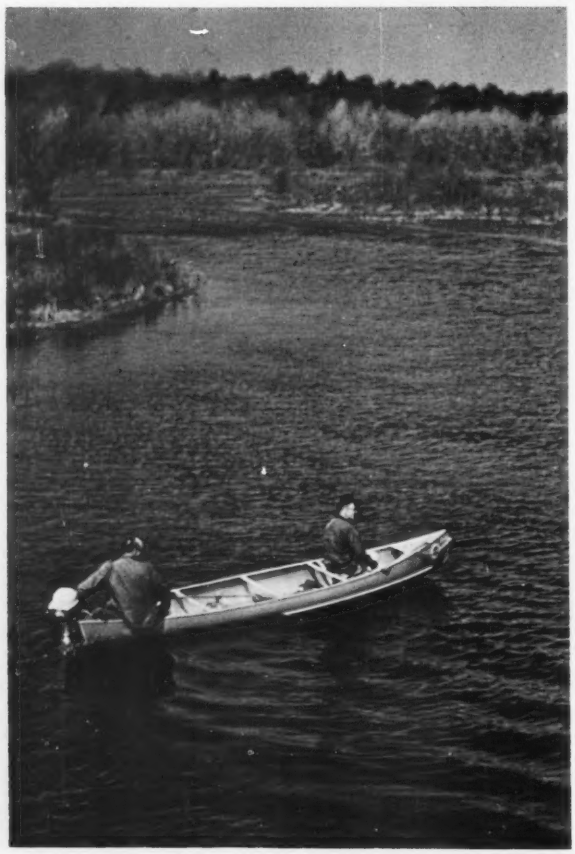
The Council recommended that the Massachusetts Fish and Wildlife Division manage the NVS areas through a lease arrangement with the Corps. The Division, which has offered to assume that responsibility, is interested in managing the substantial wildlife habitat still existing in the heart of this populated basin. It would enforce laws, stock fish, improve wildlife habitats and make the wetlands accessible to the public. Still to be worked out is exactly how the easement lands—those belonging to

conservation land trusts, for example—would fit into the state agency's plans.

The management committee's second tier, the one dealing with specific programs for specific areas, is chaired by Corps personnel. Currently, this management unit is assessing the locations and number of acres available for purchase from property owners over the next three years. Basically, the Corps will be coordinating the state agency's proposals with local interests at each of the 17 storage areas. No use or program proposed for any of the critical wetlands will be implemented unless it has local approval.

There have, of course, been questions and doubts about NVS over the past ten years. Probably the most common question has been: "What will the acquisition of natural valley storage do that flood plain zoning won't do?" The answer is that acquisition assures that the area will remain in its natural state as long as the government owns the interest in the real estate. Zoning, on the other hand, is intended to see only that flood plain development is of the proper type, and, of course, zoning codes are susceptible to change with shifts in the political climate. Furthermore, the Charles River is so dynamic and rapidly changing in character that the flood plain is difficult to define: elevations that today are suitable for development may tomorrow become part of the flood plain.

The Massachusetts Fish and Wildlife Division has offered to manage the federally acquired wetlands, which provide a substantial wildlife habitat in the heart of this populated basin.



From time to time someone from a mid-Charles community asks: "What's in it for us?" The answer is simple. If there were no wetlands absorbing the storm upstream, mid-river basin residents would no longer be secure from floods. When deprived of its age-old storage areas, the greater volume of storm water traveling at a faster speed would likely overtop the river banks along its path to the harbor.

Many have worried about the tax revenues their communities will lose when privately owned wetlands are taken off the tax rolls. The town of Millis, for example, has 23 percent of its land designated as natural valley storage. To compensate for lost taxes on these Federally acquired lands, the Massachusetts legislature has authorized reimbursements to affected towns and cities.

There has been a great deal of interest and some controversy about the recreational uses to be permitted in the critical areas. Fishing, hunting, trapping, hiking, snowmobiling and birdwatching all have been suggested. As noted earlier, permission for these activities must be approved by the ultimate management agency, the Corps and local citizens.

Perhaps the greatest controversy has been aroused by the taking of land between the water line of the record 1955 flood and the upper limit of the Corps' hypothetical standard project flood. Some residents think it unnecessary to part with land that has never lain beneath floodwaters. These fringe areas have been assigned the lowest acquisition priority.

Despite some doubts and questions NVS's course through the ten years since its conception has been amazingly smooth. Virtually every person involved with the conservation project has enthusiastically supported it, and the Sierra Club, the Massachusetts Audubon Society, and other environmental groups have described it as innovative, refreshing and precedent setting.

Although it is the first and only project of its kind in the world, NVS can be duplicated elsewhere. The State of New Jersey is considering a similar program, and several other states, as well as two Canadian government agencies, requested information about the natural valley storage program.

In fact NED has received thousands of inquiries from all over the country. Before conservation can be recommended as a flood control measure, however, three conditions must be met: extensive natural storage areas must be present; flood damage losses there must be minimal; and loss of these natural reservoirs must be imminent.

Under these conditions, acquiring critical wetlands and allowing them to continue their natural function can be a very desirable method of flood control. Certainly the experience at NED has proved that a nonstructural, environmentally oriented prevention project like this can be an effective and economical flood management choice—an alliance with nature instead of a confrontation.■

Weather Modification

by **Donald F. Kostecki**

Although "rainmaking" has been practiced since the late 1800s, it was not until the late 1940s that the term "weather modification" took on a scientific respectability. Until then, there was very little available information about the causes of weather; man's activities were mainly confined to observing the effects of weather and climate, primarily at the ground. Only after systematic measurements of the condition of the atmosphere above the ground began to accumulate was it possible to understand the causes of weather and to make reasonable predictions of how it might change in time and space. At about this same time, important discoveries were made about the formation of ice crystals in clouds. These developments in understanding of cloud physics and meteorology gave birth to the science of weather modification.

Weather modification refers to human intervention in natural weather processes, usually by the introduction of materials or "nuclei" into clouds or fog. The seeding material most commonly used is silver iodide, because its crystalline structure closely resembles natural ice. Since clouds often contain large amounts of liquid water at temperatures below freezing (32°F or 0°C), artificial nuclei are introduced to initiate the growth of ice crystals and thus start the precipitation process.

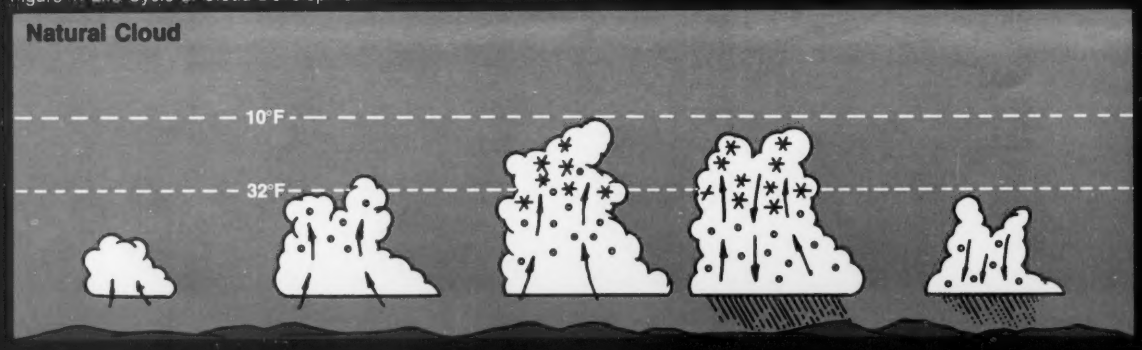
Over thirty years have passed since the initial documentation that clouds could be modified by introducing artificial nuclei into the cloud environment. Substantial progress toward refining the science has taken place during this thirty-year period, although controversy has been its companion. Almost immediately following the replication of laboratory experiments on real clouds in the late 1940s, commercial entrepreneurs began applying the technology in various parts of the world. These applications reached a maximum in the mid-1950s when approximately 10 percent of the land area of the United States was the target of operational cloud seeding projects. There followed a period of assessment culminating in a report by a Presidential Advisory Committee on Weather Control in 1957. The major recommendation of this Committee was that substantial support be given to research into all aspects of the atmospheric sciences so that fundamental understanding of the weather and its possible modification could be obtained. Responsibility for directing this research was given to the National Science Foundation.

In spite of submarginal funding for weather modification research, progress has been made: (1) in understanding weather and how it might be changed by man, (2) in the ability to effect changes in clouds and weather, and (3) in the capacity to measure both natural and modified conditions of the atmosphere. Table 1 is a list of major field experiments that have contributed to the progress of weather modification technology. On the heels of this progress, several wide-ranging reviews of the weather modification field have been undertaken.[1] The first half of

Mr. Kostecki is a meteorologist with the Kansas State Water Resources Board.

1. The reader may wish to refer to any or all of the following sources: National Advisory Committee on Oceans and Atmospheres, 1972, First Annual Report to the President and the Congress, GPO, Washington, D.C.; National Academy of Sciences, 1973, "Weather and Climate Modification: Problems and Progress," Committee on Atmospheric Sciences, NAS-NRC, Washington, D.C.; Hess, W., 1974, Editor, *Weather and Climate Modification,* John Wiley, New York, N.Y.; Bark, L. D., 1977, "Can We Do Something About the Weather?," Kansas Agricultural Experiment Station, Bulletin 605, Kansas State University, Manhattan, Kansas.

Figure 1. Life Cycle of Cloud Development



Cumulus Starts Building.

Few Large Drops Form.

Cloud Grows.

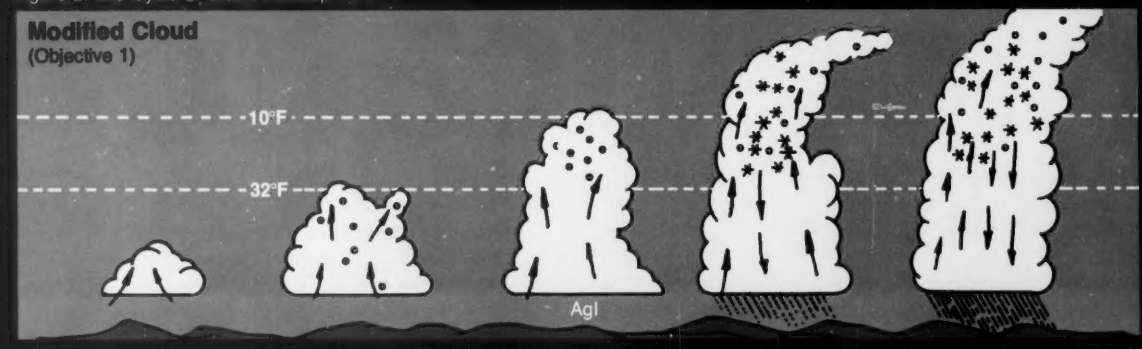
More Large Drops and Few Ice Crystals Form. Cloud Reaches Maximum Height.

(1) Ice Crystals Grow Larger at Expense of Cloud Droplets, Fall Thru Cloud, and Melt Into Large Drops.

(2) Large Drops Coalesce With Other Droplets and Grow Into Raindrops Which Fall to Ground.

Light Rain Continues As Cloud Dissipates.

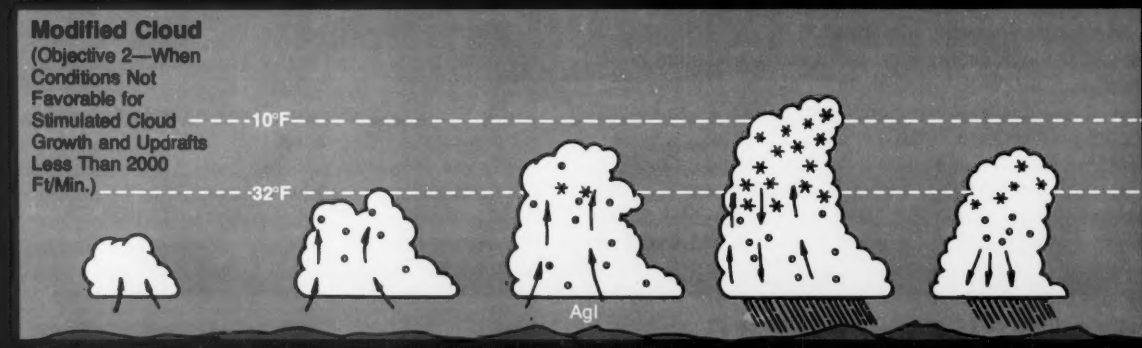
Figure 2. Life Cycle of Cloud Development



Concentrated Charge of Silver Iodide (AgI) Delivered Into Updraft of Cloud.

Great Amount of Heat is Released When Supercooled Drops Freeze, Causing Substantial Cloud Growth.

Much More Water is Processed by Large Cloud, Resulting in More Precipitation on the Ground.


Modified Cloud
(Objective 2—When Conditions Not Favorable for Stimulated Cloud Growth and Updrafts Less Than 2000 Ft/Min.)
10°F
32°F
AgI

Silver Iodide Delivered Into Updraft.

(1) Many Ice Crystals Form in Super-Cooled Region of Cloud and Grow at Expense of Cloud Droplets.

(2) Precipitation Begins When Large Ice Crystals Fall and Melt.

Moderate Rain Continues as Cloud Dissipates.

Legend
* Ice
Liquid Droplets

Time:

5 Min. 10 Min. 15 Min. 25 Min. 35 Min.

A "family" of cumulus clouds in various stages of development. Clouds respond to seeding only under certain conditions which may exist for only a few minutes during the 20 to 40 minute life of a typical cloud.

the present decade also saw the enactment of comprehensive weather modification statutes in several states, and even the initiation of state-wide application programs in a few states.[2]

Types of Weather Modification

To attempt a detailed description of the various types of weather modification either attempted or accomplished by man would be far beyond the scope of the present undertaking. However, in order to place the remarks which follow in proper perspective, it may be well to briefly describe the types of weather modification which have been studied and how progress in these various endeavors has advanced the science as a whole.

The laboratory "cloud" on which the first seeding experiment was conducted was very similar to what meteorologists call a "stratus" cloud, meaning it had a rather uniform moisture content and exhibited very little vertical motion. In nature, such clouds occur as cold and warm fog at or near the ground. Another cloud type of rather uniform structure and composition often forms as the result of the cooling and condensation of moist air forced upward by some topographic feature such as a mountain range. It is not surprising, therefore, that these two natural clouds were the target of the first seeding experiments, and are those with which a seeding effect is easiest to demonstrate. It is also interesting to note that the first type of weather modification to be practiced operationally and accepted as fact—the dispersal of cold fog—has never been subjected to statistical tests of effectiveness.

The modification of orographic precipitation, primarily winter snowpack, has been the subject of much

2. This table is not intended to be exhaustive. Several other experiments in the United States and around the world have contributed to advances in weather modification. Noteworthy projects have been conducted in Australia, Canada, Israel, South Africa, the Soviet Union and Switzerland.

scientific evaluation, and the circumstances in which such precipitation can be modified are reasonably well understood. Locations where orographic precipitation has been successfully modified include the coastal mountain ranges of the western United States and the upwind sides of several ranges in the Rocky Mountains.

The other major cloud type which has been the subject of intensive experimentation and the target of numerous operational seeding projects is the cumulus cloud. Such clouds are characterized by vertical development in the form of rising mounds, domes, or towers.

In contrast to stratus clouds, they are of smaller horizontal extent, have shorter life cycles, and are much less uniform with respect to either moisture content or internal motion. Cumulus (convective) clouds have been seeded to increase their precipitation, and to decrease the amount of associated lightning or the amount or size of hail. Cumulus clouds are also an integral part of tropical storms and hurricanes, and have thus been the target of attempts to mitigate the damaging winds and excessive precipitation associated with such storms.

Because they are the source of most of the precipitation naturally occurring in the world, cumulus clouds have historically been a prime target of operational cloud seeding projects. Agricultural and water supply interests have usually been the sponsors of such projects, with interest related to local perceptions of imminent or existing drought. Precipitation from convective clouds has been successfully increased from the sub-tropical clouds of south Florida, and limited success has also been documented in the Dakotas and several other localities around the world.

A major storm type, consisting of both stratiform and cumuliform clouds, that has been investigated to only a limited extent with reference to its modification potentials is the extratropical cyclone. Such storms are also called low-pressure systems and occur mainly in mid-latitude regions such as the continental United States. Modification of precipitation associated with these large-scale synoptic systems is a real possibility, but the complexity of such weather systems has precluded direct experimentation upon them.

A final type of modification which has received considerable attention in recent years is what has been termed "inadvertent" weather modification. Detailed measurements and statistical analyses of many weather variables in and downwind of St. Louis and other large metropolitan areas has resulted in identification of significant increases in thunderstorms and heavy rain activity, apparently related to changes in the atmosphere and its composition brought on by urbanization and industrial development.

Examination of a large number of operational cloud seeding projects undertaken in the 1950s and several experimental programs in the early 1960s revealed that results were, for the most part, inconclusive, primarily because: (1) the extremely large natural variability of precipitation, and (2) the largely indiscriminate application of seeding material with only limited understanding of when, where, and how to seed clouds to obtain a desired effect.

Large cumulonimbus cloud. The lack of an ice crystal "anvil" on a cloud of this size indicates a shortage of ice nuclei which seeding might alleviate.

Table 1. Recent Weather Modification Experiments[2]

Project Name	Location	Years Active	Contribution
Climax I and II	Rocky Mtns. of Central Colorado	1960-70	Identified criteria for winter orographic seeding.
Whitetop	Southern Missouri	1960-64	Proved non-applicability of indiscriminate seeding of summer cumulus clouds.
Santa Barbara	Coastal Mtns. of Southern California	1968-74	Identified downwind effect from seeding winter convective storms.
Cloud Catcher	Southwest South Dakota	1968-72	Developed numerical model of High Plains convective clouds.
North Dakota Pilot Project	Western North Dakota	1969-72	Identified rainfall increases from model predictions of seedability.
Florida Area Cumulus Experiment	South Florida	1970-76	Confirmed "dynamic" seedability; showed importance of cloud mergers to total rainfall.
Colorado River Pilot Project	San Juan Mtns. Southern Colorado	1971-75	Refined seedability of winter orographic storms.
National Hail Research Experiment	Northeast Colorado	1972-74	Identified types of hailstorms and role of ice in summer rainfall processes.

It has become quite apparent that many variables interact to determine whether a particular cloud or cloud system is suitable for seeding. However, progress toward defining "seedability" has been substantial in recent years. Improvements in digital computers and numerical analysis have enabled the simulation of cloud processes involved in precipitation formation. As measurements of these processes have become possible, the number of assumptions has been reduced.

The most significant factor in greater understanding of precipitation processes has been the development of instrumentation to measure the meteorological variables and atmospheric constituents which contribute to the variability of precipitation. With improvements in measurement capability, the numerical modeling of cloud processes and statistical evaluation of relationships between important meteorological variables have truly become possible. The development of instrumentation has followed closely the miniaturization of electronic components. The digitizing of data from rapid scanning devices such as radars, ice and condensation nuclei counters, multispectral scanners, and analog sensors such as thermometers has permitted large numbers of measurements to be taken over relatively short periods of time, and facilitated their analysis on computers.

As a result of close collaboration between meteorologists and statisticians, new techniques have evolved with respect to both the design and evaluation of experimental and operational cloud seeding projects. By collecting data on as many of the interrelated weather variables as possible in relatively few case studies, along with continuous monitoring of key "predictor variables" over a wide range of conditions, the number of cases needed to establish statistical confidence in the effects of cloud seeding can be drastically reduced. In other words, by simultaneously conducting both physical and statistical experiments, the length of both can be shortened.

In the area of seeding materials and delivery techniques it has been found, for example, that different mixtures of silver iodide and various combustible materials produce artificial ice nuclei which are effective at different temperatures. The type and amount of ice nuclei generated under various meteorological conditions has been tested in artificial cloud chambers which are much better replicas of natural clouds than was the home freezer unit in which Dr. Vincent Schaefer conducted the first seeding experiments. It has also been found that precipitation processes can be altered by hygroscopic materials such as common salt or urea fertilizer, through changes in the drop-size

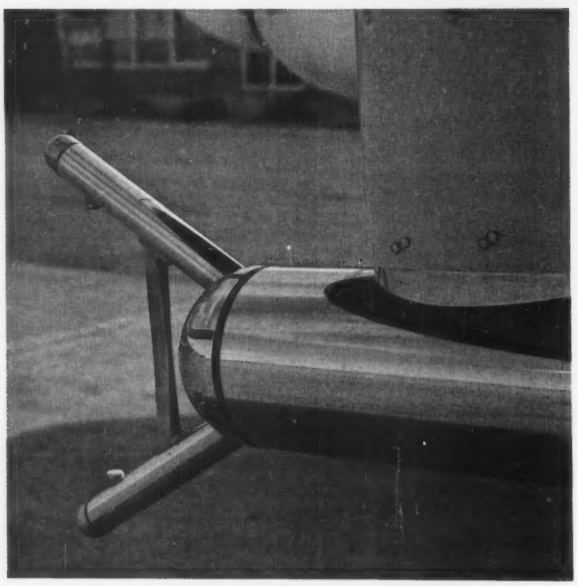
distribution in the warm (above 32°F or 0°C) portion of clouds. This technique enhances the coalescence process, whereby larger drops collide with and collect smaller ones and initiate the fall of rain earlier in the life of certain clouds. Delivery of seeding materials has also been enhanced considerably through the use of high performance general aviation and surplus military aircraft, enabling more certain injection of the seeding material into target clouds.

Even with the above cited improvements in measuring, understanding and affecting cloud processes, the reliable application of cloud seeding techniques with a predictable outcome is not yet a reality. To be sure, clouds have been deliberately and demonstrably changed, and the amount of precipitation falling from them has been measurably increased. However, the physical chain of events brought on by human intervention into natural precipitation processes is not well understood. Similarly, the transferability of techniques or results from one location or climatological environment to another, even over distances of a few hundred miles, is still largely an educated guess rather than a demonstrated fact.

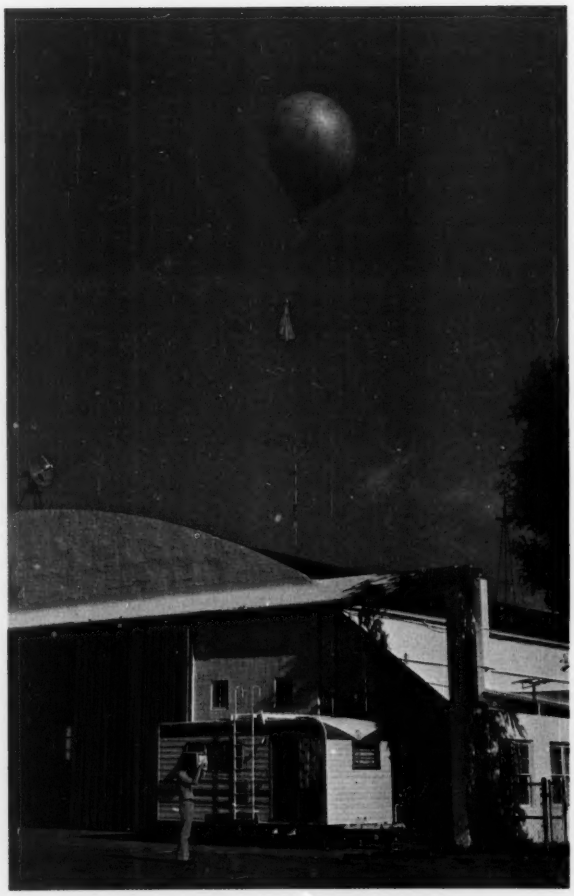
The Future of Weather Modification

It has been said that what people think about it, rather than what scientists know about it, will determine the future of weather modification. Polled opinions range from the belief that cloud seeding is so effective that to attempt it invites man-made catastrophes to the belief that it is an expensive waste of money. As with most subjects about which there is a diversity of opinion, the truth lies somewhere in between.

Agricultural interests, not surprisingly, are generally quick to support cloud seeding projects. Using even the most capable general aviation aircraft for delivery platforms; highly qualified and well paid meteorologists, pilots, and technicians; and ground-based equipment such as radars; the cost of conducting a cloud seeding program over a 15,000 sq. mi. area may range between five and ten cents per acre. When compared to other costs of agricultural production, this is indeed trivial. Crop loss insurance alone can range between $5 and $20 per acre depending upon the area and crop insured.



Cloud particle spectrometer attached to the wing of a research aircraft. This photo-electric device counts cloud and precipitation particles in a certain size range. This information is needed to determine the appropriate amount and type of seeding material.



Radiosondes are used to measure the temperature, humidity, pressure and wind patterns of the atmosphere. A balloon carries the instrument package to a height of 60,000 feet or more while a radio transmitter relays the data for nearly an hour from distances of 50 miles or more.

In view of the diversity of expressed opinions about weather modification, and the general lack of widely held public opinion on the subject, it is not surprising that a national policy for development and use of weather modification does not currently exist. It also helps to explain why Federal funding for research has remained below amounts recommended by informed and critical viewers of the field.

Independent Reviews and Recommendations

In 1972, the first annual report of the National Advisory Committee on Oceans and Atmospheres (NACOA), composed not only of atmospheric scientists but a widely

varied group of individuals from universities, government, and industry, selected weather modification as one of four topics deserving priority attention. This group observed that past efforts in weather modification had suffered from inadequate or erratic funding. They suggested that: "What is badly needed is a field experiment which brings to bear all of the resources that can contribute to the success of the experiments."[3] An updated review by the National Academy of Sciences in 1973 recommended three research goals to be pursued over the next decade. Paraphrased, these goals were:

(1) Identify the conditions under which precipitation can be increased, decreased, and redistributed in various climatological regions;
(2) Develop a technology to mitigate the effects of hurricanes, hailstorms, fog, and lightning; and
(3) Establish a coordinated program to investigate the inadvertent effects of man-made pollutants on local weather and on the climate of the world.

While progress toward these goals has continued since 1973, one cannot be optimistic that they will be achieved within the next five years.

A General Accounting Office study in 1974, and another by the White House Domestic Council in 1975, recommended greater Federal attention to the field of weather modification and the designation of a lead agency to coordinate the effort. This spurred the enactment of P.L. 94-490, which directs the Secretary of Commerce to further study the field and recommend a national policy. What will become of these recommendations is as yet unknown.

A technology assessment of hail suppression was recently completed under sponsorship of the National Science Foundation.[4] Conducted by the Illinois State Water Survey in association with several other research groups, this was a systematic attempt to anticipate the societal effects of successful application of weather modification technology. As such, it considered technical details of the present and future technology, societal factors influencing the rate at which it would be employed, public and private impacts of its application, and available policy options. Varying assumptions as to the effectiveness of hail suppression and rain augmentation were made as part of this technology assessment. The "high technology" model assumed a hail suppression capability increasing from 30 to 80 percent damage reduction between 1975 and 1995, with accompanying rain increases between 6 and 16 percent respectively.

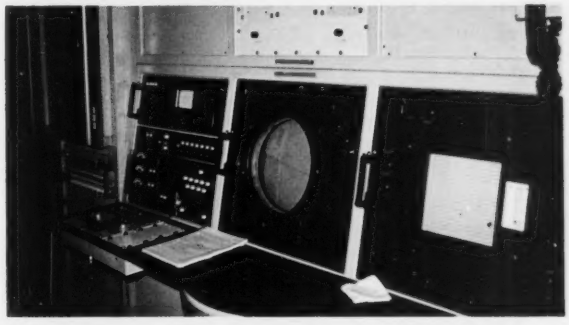
Among the more interesting conclusions of this technology assessment were that: (1) at present there is no established hail suppression technology, although it may be possible to reduce damaging hail by about 25 percent over the growing season in a properly conducted project, and (2) the economic effects of assumed increases in rainfall are more significant than those attributable to hail suppression.

This assessment recommended that the Federal government attempt to develop a hail suppression technology with a high level of effectiveness, and that monitoring and evaluation of operational projects should be funded primarily from Federal sources. The study also recommended that future hail suppression research consider the whole convective storm process, including the interrelationships among precipitation, hail, and wind.

Research and Development Needs

It should be rather apparent that a major research effort is needed to learn more about natural weather behavior and understand the atmospheric mechanisms that might be altered by weather modification techniques. While the centerpiece of a research and development program may be cloud seeding, related field and laboratory research must not be ignored—for example, energy and land-use planning and research and water development and diversion projects. In addition, experiments primarily concerned with rain augmentation should not be artificially separated from others directed toward hail suppression; and studies of the downwind, extra-area, and non-meteorological effects of cloud seeding should proceed concurrently with the meteorological experiments.

The overall goal of weather modification research should be the development of a technology which can reliably and predictably produce cloud and weather changes in various climatic regions. The transferability of techniques and results should be tested before operational programs proceed unchecked or unmonitored. The failure of many past programs, both experimental and operational, can be attributed in large measure to assumptions that measurements taken or results obtained in one location were transferable without verification to other areas. Before a technique is considered applicable to a particular locality, experimental or pilot projects results should be tested in a demonstration project, with sufficient monitoring in the new area to verify transferability.



Radar console of U.S. Bureau of Reclamation facility in Goodland, Kansas. From left to right: magnetic tape drives used to store radar return signals; control panels; plan position indicator (PPI) scope (circle); range/height indicator (RHI) scope.

3. National Advisory Committee on Oceans and Atmospheres, 1972, Op. cit., p. 27. Subsequent annual reports from NACOA have also discussed weather modification and made further recommendations. The reader is referred in particular to the 2nd, 4th, and 5th reports.

4. This Technology Assessment for the Suppression of Hail (TASH) was part of the NSF's program of Research Applied to National Needs (RANN). The final report was released in late 1977 and is available from National Technical Information Service, Washington, D.C. The fact that this assessment addressed the interrelationships between hail and rain is particularly noteworthy.

More studies are needed to quantify the true benefits and costs, both primary and secondary, of weather modification activities. The costs of cloud seeding are not just those required to obtain qualified personnel to conduct the activity, and pay for aircraft, seeding materials, insurance, licenses and permits. Responsibly conducted cloud seeding will include the cost of data collection and analysis sufficient to verify or disprove promised or claimed effects, and indemnities to those adversely, but unavoidably, affected. Costs such as these are seldom considered, much less quantified, when computing the cost of cloud seeding. Related to benefit/cost studies, sound programs of public information are needed to explain the abilities, limitations, uncertainties and risks of weather modification in plain language to the general public.

Research must, therefore, be expanded in a number of areas and across a broad spectrum of interests, in order to advance the state of the art into a reliable and acceptable technology. The real dollar costs of the needed research must be recognized and funded accordingly—at least $30 million annually in current dollars over the next 10 to 20 years. As a general rule, priority funding should be given to areas of critical uncertainty. Atmospheric scientists generally agree that cumulus cloud processes are the least understood and should therefore receive the largest share of research funds. However, it may be that legal, institutional, and other societal concerns are of greater long-range importance, and should thus be given first priority.

A Truly National Policy

The scope of the research and development needs enumerated above, as well as the national and even international implications of widespread and effective use of the technology, dictate that the Federal government must be involved in the future of weather modification. Only the Federal government has the resources to mount the major field experiments required to remove the scientific uncertainties preventing the predictable and acceptable utilization of weather modification. This is not to say that the states and even the local units of government do not have a definite role to play in the development of weather modification technology. However, the scope of the task ahead implies that the Federal government must take the lead role in furthering weather modification.

An early order of business would seem to be that all Federal agencies currently or formerly active in weather modification should cooperate and, if necessary, overlap their programs so as not to artificially departmentalize atmospheric problems. Existing coordination mechanisms are admittedly inadequate or ineffective. Special interest groups interested in furthering Federal effort in weather modification, such as the current National Weather Modification Advisory Board, are likely to recommend a separate Federal agency for weather modification. However, the Executive Branch of the Federal government is already overburdened with specialized commissions. The National Advisory Committee on Oceans and Atmosphere (NACOA) would appear to be the most logical existing entity to be handed the additional charge of pursuing a unified Federal program in the weather modification field. The mission oriented agencies already involved in weather modification should be required to coordinate their programs through NACOA.

At this stage in the development of weather modification technology, it appears inappropriate for the Federal government to involve itself in the regulation of weather modification activities. Some legislation requiring minimum and uniform components of state laws might be in order, as would Federal guidelines for the licensing of qualified persons to design or direct weather modification activities. But, the regulation of those activities should be left at the state level. States should likewise be encouraged to develop their own understanding and expertise through cooperation with an expanded Federal research and development program.

To complete a truly national weather modification policy, it would appear that decisions to apply weather modification technology should be left at the local level. Properly conducted operational cloud seeding programs might serve as the core of demonstration projects, with Federal or state assistance to permit appropriate design and evaluation. Likewise, the acceptance of the limitations and risks of applying weather modification should be assumed at the local level.

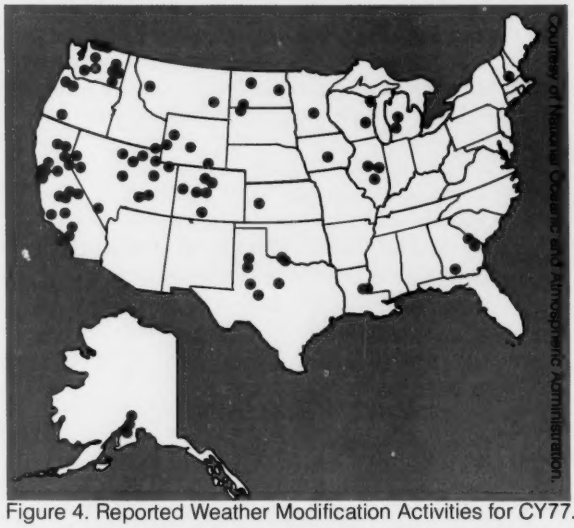


Figure 4. Reported Weather Modification Activities for CY77.

Historically, man's efforts to modify the weather have been spurred by crises such as drought or other natural disasters. For example, modification activities increased 44 percent between CY76 and 77. However, real progress of the science has followed primarily from deliberate and dedicated efforts to understand natural precipitation processes and carefully observe the consequences of attempts to alter those processes. Many of the critical uncertainties surrounding application of weather modification technology are only now becoming tractable problems. A truly national policy for weather modification must have as its foundation a thorough understanding of the abilities and limitations of the technology and must be as fully aware as possible of the consequences of applying that technology. ■

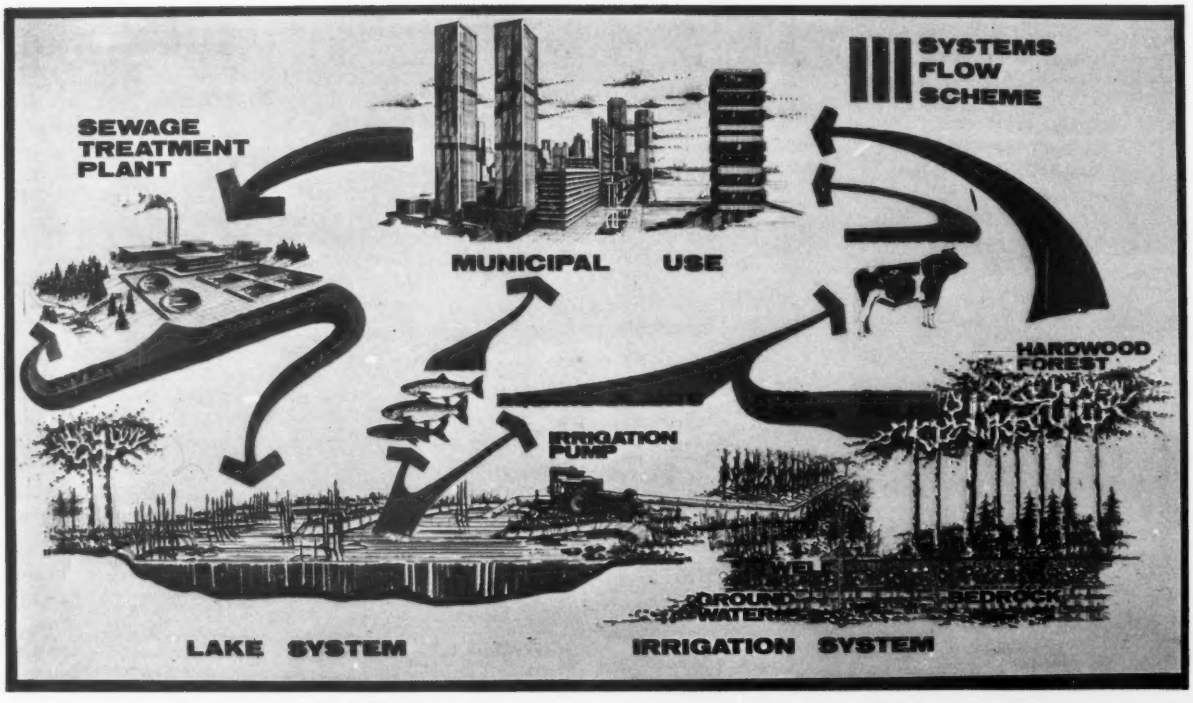
Wastewater:

By **Charles R. Downs**

A Biological Approach

An aquatic harvester cuts, gathers, and unloads a bumper crop of "aquahay."

Joe Ervin



The basic concept of the MSU Water Quality Management Project—wastewater from a city flows through the recycling lakes and spray irrigation area and returns as food and clean water.

Don't waste wastewater; recycle it. The theory is sound. Phosphorus and nitrogen are expensive fertilizers, but in municipal wastewater they harm lakes and streams. So why not take them out of the water by using them to grow food and fiber? The end results would be fish, steaks, wool, lumber and clean water rather than eutrophying lakes. But, as is the case for many good ideas, there are complex and difficult tasks between conception and implementation. The ways in which these tasks are performed can spell the difference between practical and impractical, economic and uneconomic, feasible and infeasible.

That is why the Water Quality Management Project (WQMP) at Michigan State University is important: it was specifically designed not only to actually recycle wastewater but, more importantly, to permit experimentation with various methods of recycling and research on the ecological effects of alternative modes.

Two Systems in One

Located on the southern end of MSU's 4.5-mile long campus, the four-year old project combines a 186-acre aquatic system and a 314-acre terrestrial system. The two can be used separately or together in many combinations.

The aquatic system, consisting of four man-made lakes, processes wastewater that has received primary and secondary treatment at the East Lansing, Michigan, sewage treatment plant. This water is piped 4.5 miles through 21-inch pipe to Lake One (see Fig. 1). From there, it flows by gravity to Lake Two, then to Lake Three—which is connected to three marshes—and on to Lake Four. Gates at the exits to each lake and at the lake-marsh connections regulate the flow. The final gate at Lake Four controls the flow to a ditch leading to a stream that winds its way to the Red Cedar, the same river on which the East Lansing sewage plant is located. The lakes range in size from eight acres for Lake One to twelve acres for Lake Four. They are eight feet deep at the gates and have a mean depth of only six feet, allowing the entire bottom to be covered with rooted plants.

Both algae and higher aquatic plants flourish in the nitrogen- and phosphorous-rich lakes. As these plants grow, they take up the nutrients, so that the water becomes increasingly pure as it flows through the system and, by the time it reaches Lake Four, is of very good quality. Nitrogen and phosphorus are removed from the lakes when the plants are harvested. The harvest can be used for compost or fed to livestock.

The terrestrial system, which contains 13.4 miles of irrigation pipe, receives water pumped from the inlet pipe or any one of the lakes, as desired for any given experiment. The terrestrial area is divided into several sections; any one or more can be spray irrigated at will. Some sections contain fields which have lain fallow for a few years. Others include a mature woodland of mixed hardwoods, an area planted in various kinds of crops, and a tree nursery. The different areas contain representative Michigan soil types ranging from light sand to heavy clay. This is helpful in determining not only what grows best under irrigation conditions but also what allows the greatest amount of earth-filtered water to return to the

Mr. Downs is Environmental Editor, Office of Information Services, Michigan State University. Photographs by the MSU Photo Lab except as noted.

underground supply. Returning flow is monitored by means of an extensive system of wells.

WQMP is the brainchild of Dr. Robert E. Ball and Dr. Howard A. Tanner. When they first conceived their idea in 1966, both men were professors of fisheries and wildlife at MSU. Ball also directed the MSU Institute of Water Research, and Tanner directed the natural resources area of the College of Agriculture and Natural Resources. Since then, Ball has resigned many of his administrative duties and now serves as associate director of the Institute and research coordinator of WQMP. Tanner has since become director of the state Department of Natural Resources.

It took six years for Ball and Tanner to develop their plan, to persuade the right people that they had a good idea, and to raise the necessary funds. Construction of the $2.3 million facility began in October 1972 with funding from the U.S. Environmental Protection Agency, the State of Michigan, and the Kresge, Rockefeller, and Ford Foundations. The city of East Lansing also participated, particularly by negotiating the Federal and state grants, which were made directly to the city. Basic construction was completed in the fall of 1973, and the system became fully operative in late summer of 1974.

Surprises Lead to Revised Plan

Although generally the system has functioned much as Drs. Ball and Tanner predicted, there have been some surprises. One of them is that the lakes do not retain much of the nitrogen that is piped from the sewage plant. It had been anticipated that even Lake Four would contain a fair amount of nitrogen—enough to make water from that lake suitable for irrigating plants such as corn, which requires a high level of nitrogen.

Algae grow so thick on Lake One that birds have no trouble landing on it to look for food.

When the researchers found that they were losing nitrogen from the lakes more rapidly than it was being utilized by the aquatic plants, they looked for the reason. They discovered that while the wastewater coming into the lakes is rich in nitrogen and phosphorus, it is poor in carbon. Extraction of carbon by the aquatic plants increases the acidity of the water, and therefore the nitrogen is taken up as a volatile ammonia, which readily vaporizes.

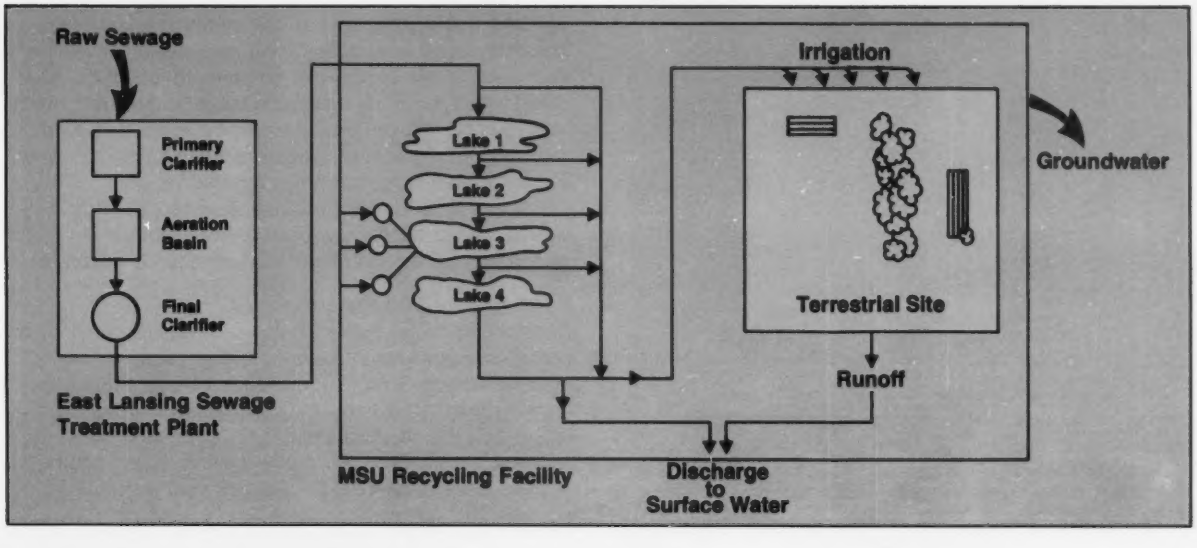


Figure 1. Four lakes and three ponds constitute the "front half" of the MSU Water Quality Management Project. Wastewater piped from the East Lansing sewage treatment plant enters Lake One and, regulated by gates, flows by gravity to the other lakes and ponds. Water can be pumped directly from the main pipe or from various parts of each of the lakes to the "back half" of the project, the spray irrigation system.

That is not all bad, the researchers reasoned, because one intent of recycling is to strip nitrogen from the wastewater anyway. Moreover, they began to feel more confident about irrigating heavily in the winter without the danger of nitrates leaching through the soil and polluting the ground water. This would be a possibility if the water contained large quantities of nitrates and there were no growing plants to take them up. (Phosphorus is not a problem in this respect because it tends to bind to the soil, so it cannot leach into the ground water.)

Out of this new knowledge has evolved a revised plan. During the summer of 1978, while plant life is growing, the nitrogen- and phosphorous-rich water coming from the sewage plant will be diverted to the irrigation area before it has even gone into Lake One. There it will fertilize the plants, whose uptake of nitrogen will prevent the nitrates from leaching into the ground water. The lakes, which will be standing full during the summer, will lose almost all of their nitrogen to the air and to the aquatic plants. By October, they are expected to be excellent, nitrogen-free sources of water—most suitable for winter spraying.

If this protocol works well, as expected, Dr. Darrell L. King, acting director of the Institute for Water Research, says he will be ready to confidently recommend such a system for small and medium-sized Midwest communities that need to build tertiary wastewater treatment systems. With one or two additional lakes on the front end, he believes, it might even be feasible to use such a system to process raw sewage.

"The main resource that a community needs to use the WQMP system," says King, "is available land reasonably close to the wastewater source. With sufficient land area, you can take advantage of solar power to remove the nutrients by energizing the plants, and you can design your wastewater recycling system relative to ecological processes."

The lakes and ponds of MSU's Water Quality Management Project.

Fallow fields are sprayed with wastewater from the recycling lakes. MSU is also spray irrigating the woods, as well as crops and a tree nursery. The squares at lower left were cut to isolate communities of field mice for ecological study.

Good economic data to compare the financial aspects of the WQMP system with more conventional treatment are lacking, but King points out that the two approaches have to be evaluated largely on the basis of tradeoffs.

"A mechanical system," he notes, "requires less land area and would probably use less energy in a large city. The energy cost of pumping great amounts of sewage for a long distance would probably be prohibitive. On the other hand, with a recycling system, you can benefit from direct solar energy, you can produce valuable products—food and fiber—and you may even have a fine municipal park. The lakes do not produce any odor, and we hope to eventually be able to demonstrate the potential of the aquatic system for fishing, boating, ice skating, picnicking, hiking and other forms of outdoor recreation."

Food Production Potential

Of all the benefits of WQMP, the food-raising potential is perhaps the most obvious—and, to the general public, the most intriguing. Soon after the lakes were first filled, they were planted with biological organisms from established lakes—mostly indigenous plants, but with them eggs, zooplankton and other aquatic specimens. A rich food chain quickly developed. Stickleback minnows in large numbers soon appeared in Lake Four and, in the early

Algae are harvested by pushing them up on the shore in large ropy masses. The algae are dried and used for compost or fed to livestock. This harvester has been replaced by a larger, more efficient machine.

summer of 1975, they were supplemented with a stock of fathead minnows. The minnows were followed a few days later by hundreds of fingerling bass, which feasted on the minnows and grew prodigiously—from one-and-one-half inches in June to eight inches in September.

"The environment is apparently ideal for the bass," says Dr. Howard E. Johnson, professor of fisheries and wildlife and director of fish research. "Their growth and maturity rates appear comparable to those for bass in Louisiana and Florida waters. The bass fingerlings planted in 1975 spawned this past summer (1977) and are now nearing two pounds in weight and 15 inches in length." Another stock of fingerling bass was planted in 1976 and is also flourishing. "We hope to establish some sort of sport fishing system so the lake doesn't become overpopulated," says Johnson.

In addition to their spectacular growth, the bass are also generally healthy and suitable for human consumption. Analyses of samples taken from the lake show them to have traces of metals and persistent chemicals no higher than would ordinarily be found in fish from Michigan lakes. The only important problem in the bass was a bacterial infection *(Aeromonas liquefaciens)* in May 1977. Lesions were found on both the one-year-old and the two-year-old fish, but only some of the mature fish died, presumably due to the combined stress of spawning and the bacterial infection.

Bass are not the only possibilities being considered. Johnson is also experimenting with catfish and carp in

Fingerling bass were planted in Lake Four in June 1975. By September they were about eight inches long, approximately twice the average first-year growth for bass in Michigan lakes. By September 1978, they averaged 12.6 inches in length, and some weighed as much as three pounds.

Wastewater is piped to and sprayed on a wooded area containing various kinds of mature hardwoods.

Lake Three. These fish are kept in cages, for easy access and study, as they would be if they were being grown strictly for food production, as opposed to sport fishing.

The plant life in the lakes is also being put to good use. Both the algae and the rooted plants are being harvested almost continuously from mid-summer through the early fall with the aid of a commercially available aquatic harvester. Most of the resulting "aquahay" has been piled up and composted for later farm and garden use. But a large amount of it has also been dried, pelletized and fed to sheep and cattle. Analysis of the aquahay indicates that it is quite similar to the terrestrial form except that the algae are richer in protein. Early indications are that livestock accept their aquatic food and are well nourished.

In the terrestrial system, the food growing possibilities are more traditional but no less substantial. Dr. M. B. Tesar, professor of crop and soil sciences, has been applying wastewater to experimental plots for four years.

"Our results show that corn, alfalfa, and grasses can be used effectively, in a single year, to remove nitrates and phosphorus from wastewater," he reports. "There is little if any contamination of the soil, water, or streams."

Some crops, such as alfalfa, are better at removing phosphorous, while others, such as corn, more effectively remove nitrates, Tesar has learned. Continuing experimentation is expected to lead to optimum patterns for communities to follow when they adopt biological recycling.

Meanwhile, researchers from MSU's Department of Forestry have been looking at the growth of young trees under wastewater spray irrigation and learning that fast growing trees with large biomass are more effective for cleaning wastewater because they usually take up more nutrients than slow growers.

"Cottonwood, a fast-growing species, combines high nutrient concentration with large biomass production and is the species exhibiting the greatest overall nutrient assimilation," notes Dale G. Brockway, a graduate research assistant assigned to the forestry project. His experiments also give good marks to sycamores, black walnuts, and Scotch pines. Norway spruces, white spruces, black cherries, tulip-poplars, white ash and red oaks have not performed as well but may do better proportionally when they gain greater size, says Brockway.

Water from the recycling lakes and water pumped from underground at various depths and locations is regularly analyzed in this MSU laboratory.

Conditions Monitored Closely

WQMP researchers are confident that they are gaining sound data from their experiments because conditions in both the terrestrial and aquatic systems are regularly monitored. This capability was part of the original planning, which provided for 41 drift wells, 14 shallow rock wells and four deep rock wells strategically positioned throughout the study area and designed to guard against accidental contamination.

Composite samples of the raw, primary and secondary effluents are taken at the East Lansing sewage treatment plant every day. Similarly, samples are collected daily from the influent of each lake and the final effluent from Lake Four. In addition, the wells and lake sediments and the aquatic plants are sampled periodically. More than 50 chemical, physical and biological variables are monitored as these samples are analyzed. The ultimate outcome of this data collection program, which was devised by MSU water chemist Dr. Frank M. D'Itri, is a comprehensive view of the dynamics of both the aquatic and terrestrial systems. Abnormalities or trends in water or biological quality can readily be noted.

Unfortunately, viral activity, the most important and most controversial aspect of water quality measurement, cannot yet be routinely tested with any degree of accuracy. Many questions of viral contamination in a system such as MSU's—and in other water or sewage systems—remain essentially unanswered because there are no quick, standardized tests that would permit technicians to detect viruses as readily as they now detect disease-causing bacteria. Viruses have been found not only in sewage plant effluents but in chlorinated drinking water. The problem is that, while it can sometimes be determined that a virus *is* present, it is extremely difficult to be certain that virus *is not* present in any given water sample. So, and even though conventional sewage treatment and water supplies are not ordinarily checked for viruses, public health authorities tend to be concerned that biological recycling might not eliminate all disease-causing viruses. It may therefore be necessary to find ways to demonstrate clearly the absence of viruses in systems such as MSU's before biological recycling finds full acceptance by regulatory health agencies.

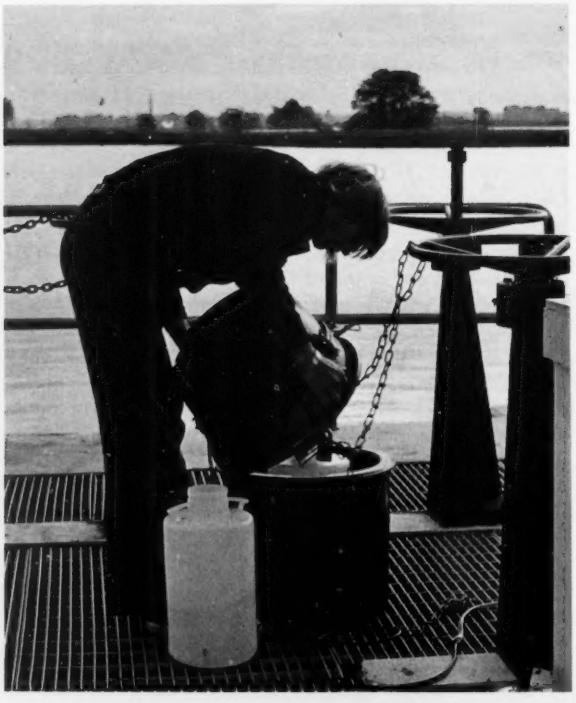
Many Aspects Researched

WQMP is more than a project to determine the most immediately effective methods of recycling wastewater by biological processes. A thorough attempt is being made to understand the total ecological impact. For example, even before WQMP was built, the ground and surface water in the area was studied so that there would be a good data base with which to compare all subsequent findings. Similarly, the flora and fauna of the area were carefully catalogued and are now regularly monitored so changes that take place as a result of biological recycling will be observed and recorded.

Of particular interest is the possible growth in numbers of *Aedes triseriatus,* the mosquito species that is the major carrier of California encephalitis. This species prefers to lay its eggs in stumps, holes along tree trunks and in various human artifacts that collect water—tin cans, tires, and so on. MSU entomologists are concerned that the heavy spray irrigation at the site might provide a good ecological niche for the encephalitis carrier. They have evidence that another Michigan site for spray irrigation has already experienced an increase in *Aedes triseriatus*.

Spray irrigation might also provide an optimal environment for midges. These are small, mosquito-like insects that plague lakes and sewage lagoons in California much of the year but have not been an important problem in Michigan due to its cooler summers. However, because midges reproduce so well in shallow ponds, there is concern that widespread adoption of biological recycling might lead to a great increase in the Michigan midge population. Entomologists are studying the potential problem. The focus of study is not just on insects, but also on insect predators and other life forms, for example, the bird population. At any given time, 20 or more discrete

Crops nourished by wastewater spray irrigation are carefully harvested and weighed to obtain useful experimental data.



A technician samples water from one of MSU's four recycling lakes. More than 50 chemical, physical, and biological variables are monitored.

research projects may be in progress at the WQMP. Some may not be related directly to wastewater recycling but may simply utilize the facilitities that are provided—for example, a study of the frog population in one of the man-made marshes.

The design of this 500-acre outdoor laboratory, tne flexibility with which it can be operated, and the monitoring that is routinely carried out combine to make it one of MSU's most valuable scientific resources as well as a means of demonstrating and testing various modes of biological recycling.

Added Values

From the inception of the idea, WQMP has been seen as an ideal site for demonstrating the potential of using biological recycling parks for recreation and ecological education. MSU officials have wanted to build on and landscape the aquatic system to provide for picnicking, boating, and hiking. A swimming pool and an educational center have also been considered. But at this time, there are no funds available and, therefore, no definite plans for such activities. Moreover, the continuing question of viral contamination could delay extensive public use of the facility.

Water is pumped from under the ice and onto the surface of Lake Four to prepare it for public skating.

Nevertheless, small but significant progress was made during the past winter with the help of MSU's intramural sports officials. The Institute for Water Research flooded a large section of Lake Four for public ice skating. Although that effort was soon rendered fruitless by an exceptionally heavy and long-lasting snowfall, plans are being made to try again next winter. The major problem is finding an effective and economical way of keeping the ice clear of snow. If one can be found, researchers are confident that the pond will attract skaters and that the added light penetrating the ice will increase plant growth—and uptake of nutrients—during the winter months.

The potential for recreation adds yet another possible benefit to the already impressive list of advantages to biological recycling of municipal wastewater. If the few lingering doubts about the system can be cleared up, many communities—especially those being required by the Environmental Protection Agency to install tertiary wastewater treatment—may find biological recycling an attractive alternative to conventional sewage treatment technology. In fact, with the Clean Water Act of 1977 providing communities a funding bonus for wastewater recycling and requiring that a portion of Federal sewerage subsidy funds go to recycling projects, many communities are likely to turn to Michigan State University to learn how the WQMP system can be adapted to fit their needs. ■

Events, Deeds & Deliberations

Western Snag Boats

by **Robert F. Cairo**

Since its habitation America has evolved a variety of specialized watercraft—each built for limited and specific tasks on rivers, canals, harbors and the open seas. From birchbark canoes to nuclear submarines, the parade is of staggering diversity and historical importance.

One of the most interesting of the species is the *snag boat,* which originated on the rivers of the west, particularly the Mississippi, Missouri, Red and Ohio. These major water avenues were subject to continual erosion, which undermined the banks, toppling trees into the water. With their roots or branches embedded in the bottom and trunks floating at or near the surface, these trees became snags, endangering boats on the rivers. As these hazards gathered in a channel, trapping more of their kind along with other waterborne debris, they formed rafts, which grew to giant proportions and often threatened to halt river traffic completely.

Snags caused a higher percentage—42 percent—than any other single cause of western river steamboat accidents between 1811 and 1851. When the SHEPHERDESS hit a snag three miles from St. Louis in 1844, nearly 100 persons lost their lives. Snags hampered troop movements vital to military campaigns, particularly on the Mississippi. Commerce suffered.

In 1823 the Federal government offered a prize of $1,000 for the best plan for snag removal. Removal presented no great engineering difficulties, but funds to finance the work were lacking, as was an understanding among officials of how to proceed.

The $1,000 prize was awarded to John Bruce of Kentucky in 1824. All he had to do to collect was remove all snags from the Ohio and from the Mississippi between the mouth of the Missouri and New Orleans! Bruce's prototype snag boat consisted of a pair of stout flatboats placed 8 or 9 feet apart and connected by strong cross-timbers. A sturdy framework supported a powerful windlass several feet above the boat. In the center of the windlass, between the two flatboats, was a big wheel on which a chain was wound.

The boat would be positioned over the snag and the chain made fast to it. Turning the windlass, the crew broke the snag loose and raised it enough to saw it into pieces. Bruce's boat worked slowly, and it could not handle the really obstinate or big snags. When his appropriation was exhausted in 1826, he gave up in failure.

In 1826, Henry Shreve was appointed to superintend western river improvements, and one of his first innovations was a plan for a double-hulled, steampowered snag boat. The War Department, charged with ensuring western river navigability—and still smarting from Bruce's failure—procrastinated until 1828, when it gave its reluctant approval to steam. The first Shreve-inspired snag boat—the HELIOPOLIS—began operation in 1829. It was configured essentially like the Bruce boat, except for the steam powerplant. Steam made the difference. The HELIOPOLIS and her sister the ARCHIMEDES became known as "Uncle Sam's Toothpullers" because they could handle snags weighing up to 75 tons and measuring up to 60 feet long.

By the end of 1830 the Mississippi had largely been cleared of the age-old drowned forest. But the ultimate test was yet to come.

By 1828, the Great Raft of the Red River had become an insufferable nuisance—an immovable force—to both military and commercial movement. It formed a huge dam, causing water to overflow the banks and shutting down waterborne commerce. From near Natchitoches, Texas, the Great Raft extended about 150 miles upriver. Shreve was asked to clear it.

In April 1833, the ARCHIMEDES attacked the raft. She was joined by three government tenders and 160 crewmen. When work began, much of the land bordering the Red was swamp and wilderness. By the spring of 1838 the raft was cut through. A continuous line of plantations followed Shreve's progress northward.

Removing snags continued to be a major part of maintaining western waterways. Between November 1842 and July 1845, at the height of their activity, snag boats cleared from the Mississippi, Missouri, Ohio and Arkansas Rivers over 21,000 snags, almost 37,000 roots, logs and stumps, and nearly 75,000 trees about to fall into the water.

Snag boats rendered important service throughout the 19th century—so much so that the 20th century finds them still being used by the Corps of Engineers. ■

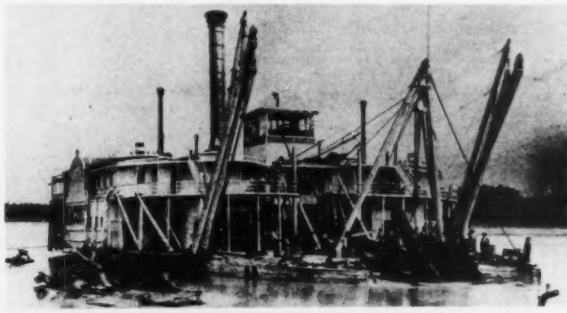


Photo courtesy of St. Louis District, COE

The JOHN N. MACOMB, built at Covington, KY in 1874, was an iron-hulled snagboat employed on the Mississippi. The hull is divided at the bows, and a large snag is suspended from the A-frame. Another snag is being pulled aft on rollers, and the heavy snag chain winding on the elevated windlass is clearly visible.

Dredge Designer to the Corps

by **Borys M. Prokopovych**

The U.S. Army Corps of Engineers' Philadelphia District is currently celebrating its 40th year as the one Corps district charged with providing the workhorse of the Corps' navigation mission, the dredge. Since 1938, the Marine Design Division at Philadelphia has conceived 13 seagoing self-propelled hopper dredges and developed dredging equipment and systems now in widespread use throughout the marine industry.

Through the years, the Philadelphia District has pioneered a number of marine design innovations. In 1924, full pilot house control of a vessel was introduced and incorporated on all dredges. In 1958, the Corps introduced controllable pitch propellers on the dredge HARDING; previously their use had been limited to Europe. In 1960, the District introduced the bow thruster to the United States on the dredge MARKHAM. This propeller located at the forward end of a ship provides lateral thrust to assist in maneuvering and docking. The District was also among the first to install sewage equipment on its vessels, and it developed the first system of dredge process instrumentation.

The Philadelphia District can also boast of innovations in dredged material disposal systems. These advances were necessitated by the District's mission of maintaining navigation in the Port of Philadelphia, which requires removal of an average of eight million cubic yards of material annually. Prior to 1954, the method of disposal was open water disposal, either in deep water in the bay area or in areas adjacent to the main ship channel, with the use of hopper dredges, which draw up spoil material from the channel bottom through drag arms and deposit it in on-board hoppers. Open rehandling basins were used when onshore disposal sites were unavailable. These basins were operated in pairs. One was dredged out by a pipeline dredge while the other was filled with material from the channel dredged by a hopper dredge. But light silt was carried out of the basins by river currents, and much of it returned to the main channel.

Dredging to remove shoals in the lower Delaware River took out more than three times the estimated amount of shoaling taking place without any improvement in the depth of the channel. Obviously, bottom dumping into rehandling basins was not effecting the complete removal of the dredged material. To make dredging more efficient, the Philadelphia District evolved the idea of unloading the hopper dredge through self-contained discharge lines to a rehandling barge or vessel located at mooring stations along the river. From these locations pipelines would transfer the material to onshore disposal areas.

By 1963, this method of disposal had been perfected. It reduced the number of dredge-months annually from 22 to 10, while producing a better channel for navigation. Further studies led to the development, in 1964, of a system known as "direct pump-out," which enables a single hopper dredge to connect to a mooring barge and pump out its hoppers directly to onshore disposal sites.

Today the District's COMBER dredges the Delaware using the direct pump-out method of disposal. After filling its hoppers to a capacity of 3,710 cubic yards of material, the COMBER makes its way to a mooring barge located near the dredging area. Pumps on board the COMBER empty spoil material through the barge's discharge pipe, which carries the material to an onshore disposal site. None of the material returns to clog the channel, and when it dries it can be used for construction fill.

A hopper dredge's dragarm, which sucks up spoil material from the channel bottom and pumps it into on-board hoppers.

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In February Ernest P. Fortino, chief of the Marine Design Division since 1975, won the Army's second highest civilian award—the Department of the Army Decoration for Meritorious Civilian Service—in recognition of his unique developments in dredging instrumentation and for increasing the efficiency of the Corps' dredges. Among his achievements are designs for three new hopper dredges which will reflect improvements in dredge technology and advance the state of the art.

The first, a small and shallow 12-foot draft hopper dredge, primarily for use on the west coast, is capable of moving 900 cubic yards of material. The second and largest hopper dredge, designed with the problems of the Mississippi River Delta in mind, will be 409 feet long, displace about 17,000 long tons, and have a hopper capacity of 8,400 cubic yards. The third, for Gulf Coast service initially, will be 350 feet long and have a 5,500 cubic yard hopper capacity. The latter two dredges can also be utilized for beach nourishment, which is an increasingly frequent use of hopper dredges.

For the future, the Marine Design Division is planning to design equipment which will completely automate the dredging process. ■

Changes of Command

Major General Richard L. Harris is the new North Central Division Engineer, Chicago. General Harris was most recently Commanding General, Fort Leonard Wood, Mo. He is a 1951 graduate of the U.S. Military Academy.

Colonel James G. Ton has been named as Philadelphia District Engineer, and is scheduled to assume that post in late July. He replaces **Colonel Harry V. Dutchshyn,** and was most recently Deputy Chief of the Research and Development Office, Office of the Chief of Engineers.

Colonel James Ellis, Executive Director, Engineer Staff, Office of the Chief of Engineers, Washington, D.C. is the latest Corps of Engineer Officer to be selected for brigadier general. His new assignment had not been announced at press time. **Colonel Hugh Robinson,** Los Angeles District Engineer, has been nominated for promotion to brigadier general, and is slated for assignment with the Office of the Chief of Engineers in Washington, D.C.

Colonel Walter C. Bell will become the new Kansas City District Engineer in August, succeeding **Colonel Richard L. Curl.** Colonel Bell has been Director of the Army Corps of Engineers Studies Center in Washington, D.C.

Colonel Robert C. Bening will become Tulsa District Engineer in late July, succeeding **Colonel Anthony J. Smith.** Colonel Bening has previously served in Washington as Public Affairs Officer for the Corps of Engineers, and as a Special Assistant to the Chief of Engineers.

Colonel Thomas A. Sands has been named District Engineer, New Orleans District. Colonel Sands is currently with the U.S. Army Military Personnel Center in Alexandria, Virginia. He will assume his new post July 15, succeeding **Colonel Early Rush III.**

Colonel James R. C. Miller began serving as District Engineer, Chicago District on July 10. He succeeds **Colonel Andrew C. Remson, Jr.** Colonel Miller was Commander and Director of the U.S. Army Facilities Engineering Support Agency at Fort Belvoir, Virginia.

Colonel Ralph A. Luther will become Japan District Engineer effective July 17. He succeeds **Colonel John T. Miller.** Colonel Luther was most recently the assistant chief of Construction Operations Division, Civil Works Directorate, Office of the Chief of Engineers.

Colonel Dale K. Randels became District Engineer for Little Rock, Arkansas, effective June 26. He succeeded **Colonel Charles E. Edgar.** Colonel Randels was the Director of Facilities Engineering at Fort Campbell, Kentucky.

Colonel Joseph A. Yore became Pittsburgh District Engineer, Pittsburgh, Pennsylvania, effective July 5. He succeeds **Colonel Maximilian R. Janairo.** Colonel Yore was formerly the Director of Evaluation at the U.S. Army Engineer School, Fort Belvoir, Virginia.

Colonel Frederick W. Mueller, Jr., has been named Rock Island District Engineer, effective August 14. Colonel Mueller will succeed **Colonel Daniel L. Lycan.**

Colonel Douglas L. Haller has been named Norfolk District Engineer, effective July 17. He will succeed **Colonel Newman Howard.** Colonel Haller is currently serving as Director of Facilities Engineering at Fort Eustis, Virginia. ■

Bookshelf

Regimes for the Ocean, Outer Space, and Weather by Brown et al addresses national governments' response to the international need to husband and allocate fairly the resources of the biosphere. The authors argue for the creation of new international agencies to coordinate the disparate private and governmental activities affecting the oceans, the atmosphere, extra-terrestrial space, and the weather. Published by the Brookings Institution, 1775 Massachusetts Ave., Washington, D.C. 20036.

Wastewater Renovation and Reuse, edited by Michigan State professor Frank D'Itri, is the third in a series on Pollution Engineering and Technology. The work presents selected papers from the International Conference on the Renovation and Reuse of Wastewater Through Aquatic and Terrestrial Systems. Available from Marcel Dekker, Inc., 270 Madison Avenue, N.Y., N.Y. 10016.

Marine Fisheries Review, the National Marine Fisheries Service's monthly journal, publishes technical articles on a wide variety of issues related to the marine fisheries and aquaculture. Recent papers have dealt with fish diseases, marine pollution, tuna fisheries, the economics of Gulf of Mexico red snapper-grouper fishing vessels, shrimp trawling development, and more. Subscriptions are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. ■

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